INFORMATION FOR AND APPROACHES TO FORAGE ALLOCATION

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PREFACE

Issuance of this volume fulfills the terms of contract number AA-854-PH1-668 between the Bureau of Land Management, United States Department of the Interior and Dr. George M. Van Dyne of the Department of Range Science, Colorado State University, Fort Collins, Colorado. Previously Dr. Van Dyne had undertaken "An Administrative Study on Application of Optimization Methods to Decision Making in Forage Allocation," contract number YA-512-CT8-260, with the Bureau of Land Management. During the course of that study, a number of progress and summary reports were issued to the funding agency, the last six of which are included in this volume. The dates of issue for chapters A through F respectively were: April 1980, April 1980, June 1980, November 1980, July 1980, and June 1981. A graduate student who worked under Dr. Van Dyne's supervision, P. T. Kortopates, is primarily responsible for chapters A and F. A research associate who worked with Dr. Van Dyne, Dr. J. W. Skiles, is primarily responsible for chapters B through E.

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DEDICATION

In August, 1981, Dr. George M. Van Dyne, Professor of Biology in the Department of Range Science at Colorado State University, died at the age of 48. It is to his memory for his many contributions to ecology and grassland management that this volume is dedicated.

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ADDENDA

Since the information in Chapter D was compiled and the report issued, several publications have been released which pertain to the topic of large herbivore diet composition. These are:

Everitt, J. H., and C. L. Gonzalez. 1979. Botanical composition and nutrient content of fall and early winter diets of whitetailed deer in south Texas. Southwestern Naturalist 24:297-310.

Hobbs, N. T., D. L. Baker, J. E. Ellis, and D. M. Swift. 1981. Composition and quality of elk winter diets in Colorado. J. Wildl. Manage. 45:156-171.

Seegmiller, R. F., and R. D. Ohmart. 1981. Ecological relationships of feral burros and desert bighorn sheep. Wildlife Monographs No. 78. 58 p.

Tueller, P. T. 1979. Food habits and nutrition of mule deer on Nevada ranges. Agric. Expt. Sta., Univ. of Nevada, Reno. Final Report, Federal Aid in Wildlife Restoration. Project W-48-5, Study 1, Job 2. 104 p.

A thesis produced using the information contained in this volume is:

Kortopates, P. T. 1981. Optimization models for allocating forage to combinations of large herbivores. M.S. thesis. Range Science Dept., Colorado State Univ., Fort Collins. 127 p.

INTRODUCTION

A common problem among rangeland resource managers and users is determining the best mixture and numbers of different large herbivore to stock on a grazingland composed of varying amounts of different plant forage species. Each forage species may have associated with it different allowable use levels and different relative preferences for it expressed by large herbivores. Also, there may be restrictions on the number of large herbivores which can remain on an area for a season or for the entire year. Independent of the use of a given forage species, the overall standing crop of herbage necessary to maintain the range site must be considered and depends partly on slope, soil conditions, and exposure. Essentially, the problem is one of how to allocate the different forage species to the various herbivores and yet not over utilize the range resource.

Various ways of approaching this problem have been proposed. Initially, the methodology of forage allocation was restricted to the single season case and was concerned primarily with determining the carrying capacity of the range. Hunter et al., (1976) proposed a serial linear programming model which accounts for uncertainty in estimating seasonal forage production while optimizing economic revenues. This is different from other earlier single species models (c.f. for example D'Aquino 1974) in that the emphasis is on the determination of a maximum grazing load in animal numbers rather than maximizing net dollar returns.

The key species approach (Smith 1965) attempts to maximize the combined relative contribution of the forage species utilized. The degree of utilization, determined <u>a priori</u>, of one or more key species is limited level of proper use. Smith (1965) used the data of Cook (1954) to calculate forage factors for cattle and sheep under common use and each grazing alone. He demonstrated the necessary conditions for which common grazing could increase the carrying capacity, the criterion being that the combined utilization of all forage species must be greater for a particular combination of herbivores than either herbivore grazing alone. All this is subject to the constraint that the key species are not utilized beyond their allowable use.

The limiting factor approach to forage allocation (Gumbmann 1978) considers the overall diet of the herbivore and the subsequent grazing load on all forage species. With this approach, the key species are determined after comparing production and utilization figures as the most limiting and most susceptable forage species to overgrazing. This is to assure that the true key species are identified and protected.

The limiting factor approach does not consider a combination of herbivores directly. Rather, the manager must decide on a system of priorities for the animal species under consideration (Jensen 1981). The manager can allocate forage within a safe level but can not determine an optimal combination of herbivores with respect to maximizing the forage grazed. With an increase in the number of herbivores being considered, use of this method means that the assigned allocation priorities must become increasingly more arbitrary. The limiting factor apporach is best suited to estimating the carrying capacity for the single season case only.

Perhaps the first to address common use and consider all of the forage at the same time were Van Dyne and Rebman (1967). Their linear programming model, implemented in a bio-economic context, considered cattle, sheep, goats and deer grazing grasses, forbs and browse. Constraints were used to limit the impact of the various herbivores on the vegetation. The optimization formulation solved for the number of herbivores of each species that maximized monetary returns.

Connolly (1974) also applied linear programming to maximize range utilization. This model was formulated to maximize the forage grazed subject to forage availability constraints which incorporated allowable use factors. His approach represents the first optimization model that was directly concerned with common use and all of the forage species with respect to range utilization. Although the model used just two animal species, it may be used to consider any number of animal or forage species.

Van Dyne (1978) presented a quadratic programming formulation for four animal species: cattle, bison, sheep, and pronghorn. This objective function was formulated as a least squares model to minimize the difference between the available herbage and the grazed forage. The formulation placed greater emphasis on utlizing the more abundant forage species than did the linear model of Connolly (1974). The model determined the optimal combination of herbivores in terms of percent grazing load with knowledge of percent herbage composition and range utilization.

The most quantitative method of forage allocation to be implemented thus far by decision makers is perhaps the lineear programming model of Martinson (1981). The model is formulated to maximize the total forage grazed throughout a Bureau of Land Management allotment. The objective function is subject to plant maintenance constraints which insure that grazing does not exceed a forage species' allowable use factor. There are other plant maintenance and resource use constraints as well as those imposed by management considerations. These latter set upper and lower bounds on animal numbers at the allotment level.

The following chapters detail a set of optimization models which address the problem of forage allocation. The first chapter presents the concepts and formulations of these models. The second, third, and fourth chapters address specific biological variables that are thought to be integral components of the optimization formulations. These are proper use values, forage intake rates, and botanical composition of large herbivore diets, respectively. The fifth chapter discusses preference for forage species and the inclusion of that variable in an optimization framework. The final chapter reports on the results yielded by the models presented in the first chapter.

The editors feel that the first and last chapters offer a means of studying forage allocation with a variety of mathematical formulations. The intervening chapters present material, derived primarily from the scientific literature, is of a more biological (rather than mathematical) nature and is of interest to managers without the optimization models. It is hoped that the conclusions and summaries presented herein will stimulate discussion and research within and among natural resource management agencies.

CHAPTER A

CONCEPTS AND FORMULATION OF ALTERNATIVE OPTIMIZATION MODEL STRUCTURES

ABSTRACT

The purpose of grazing allocation optimization models is to maximize the utilization of range forage production, subject to biological and other management constraints. This chapter focuses on the logical development of an objective function and constraints for several formulations of optimization models. Deterministic forms include linear and quadratic models with weighted and nonweighted versions. The stochastic versions of the above deterministic formulations are presented through use of chance-constraints and adjoined penalty functions. Alternative means of dealing with uncertainty are presented in a discussion of stochastic dynamic programming and linear programming under uncertainty. Several algorithms for optimization models are available and are discussed relative to the various forage allocation model formulations developed in this chapter.

CHAPTER A

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1.0 INTRODUCTION

In the last decade, various methods have been proposed for determining range forage allocation schemes for native and domestic herbivores on grazinglands. Goals in these proposed management schemes range from maximizing profit of differing livestock systems to making full use of the grazinglands carrying capacity.

When maximizing profits is the primary concern (Rogers and Peacock 1968, Pearson 1973), the focus of attention is on forecasting the future standing crop through a prediction of expected precipitation and various economic factors of livestock management. The use of such relationships, as uncertain as they are, may result in even greater uncertainties in the future welfare of native grazinglands since little attention is given to the biological factors which drive the economics of the livestock system.

A more biological interpretation of forage allocation by Workman and MacPherson (1973) attempts to measure forage accordingly. Thus, seemingly more concern is put into maintaining the range, but the total lack of biological methodologies in determining a carrying capacity do little to help such a management scheme protect the future of the native grazinglands, than in the economic scheme mentioned above. In fact, a working knowledge of carrying capacity of the range is determined by the above authors over time by trial and error and then it is assumed to be known with complete certainty.

In order to consider the future welfare of the range before allocating it, one must consider the dynamics of the system as well. The degree of utilization and preference for range plants by large herbivores is not well understood, nor are the effects of grazing on various plant communities. However, by focusing principally on the biological factors of the system, the future state and welfare of the range can be made more certain and positive steps can be taken to insure that there is always an adequate supply of forage to allocate.

Ecological problems can be formulated and solved by mathematical reasoning. The concept of optimization is now well rooted as a primary tool of analysis for decision or allocation problems. Optimization models are mathematical representations or abstractions of the real world. By no means do these formulations represent the only possible formulations as many different versions can be constructed to address the same problem. In an optimization model the decision maker seeks the values of unknown variables in an objective function. The decision maker seeks to minimize (or maximize) the value of the objective function. In attaining this optimum, the unknown variables can not be selected arbitrarily. These unknown variables appear singly or in combination in one or more constraint relationships.

Using optimization theory, it is possible to approach a complex decision-problem of allocating range forage production by focusing on a single objective, subject to constraints of minimizing the amount of allocated available vegetation left after grazing. As with all quantitative techniques of analysis, each particular optimization formulation should only be regarded as an approximation. Certain formulations are, of course, more accurate than others, but there is always a trade-off between the conflict of formulating a model which is sufficiently complex to accurately depict the problem and formulating a model that is tractable.

The purpose of the grazing allocation models considered in this chapter is to maximize the utilization of range forage production, and is presented as an optimization problem. The twelve models presented are variations of four distinct models: (i) linear, non-weighted; (ii) linear, weighted; (iii) quadratic, weighted, least-squares model, and (iv) the deterministic equivalent of some stochastic versions of the above.

2. DETERMINISTIC FORMULATIONS

The following sections present development of various formulations of the mathematical programming problem. They range in complexity from simple (linear, non-weighted, single-season) to complex (nonlinear, weighted, multiple-season). The reader is referred to Appendix I for a definition of the variables, symbols, and notational conventions in this chapter and in Chapter F.

2.1 Linear, Single Season Model

The objective of the problem can be stated as minimize the amount of available forage after grazing or:

$$\text{MIN } [A - G] \quad \text{where} \quad A \geq G \tag{1}$$

and, A represents the total amount of plant material available and G represents the total amount of plant material grazed. Since we must consider a number of herbivore species as well as a number of plant species or functional plant groups, expression (1) is expanded to:

$$\text{MIN } [\sum_{i}^{Q} a_i - \sum_{j}^{F} x_j \cdot R_{ij}] \tag{2}$$

where a_i represents the total amount available of plant group i (i = 1 to Q) in kilograms of biomass, x_j represent the unknown decision variables of herbivore species j and R_{ij} represents the total grazing rate requirements of herbivore species j for plant species i in terms of kilograms per animal of vegetation biomass (j = 1 to F).

Further, consider that the total mass of plant material available for grazing (A) is made up of the standing crop available from last season (S), an additional gain in the standing crop (G), where both S and G are in $kg \cdot ha^{-1}$ and a proportional loss due to decay, trampling, and shattering (L). The forage available is further constrained in order to allocate only the level of allowable use (U) of each specific plant group. Finally, the total biomass available is determined by multiplying density of herbage available ($kg \cdot ha^{-1}$) times the number of hectares (H) so that A of (1) may be represented as:

$$A = \sum_{i}^{Q} H \cdot u_i (s_i + g_i)(1 - l_i). \tag{3}$$

The total grazing requirement for each herbivore (R) is made up of the herbivore's daily consumption (or intake rate) (C), in terms of $kg \cdot day^{-1}$, and the preference of each herbivore j for each specific plant group i, a proportion that sums to one over all plant species or plant groups. The daily grazing requirement is then multipled by the total number of days (t) so that the term to the right of the minus sign in equation (2) becomes:

$$\sum_{j}^{F} x_j \cdot R_{ij} = t \sum_{j}^{F} x_j \cdot c_j \cdot D_{ij}. \qquad (4)$$

Combining the expanded expressions (3) and (4), the objective function is:

$$\text{MIN } [\sum_{i}^{Q} (H \cdot u_i(s_i + g_i)(1 - l_i) - t \sum_{j}^{F} x_j \cdot c_j \cdot D_{ij})]. \qquad (5)$$

The aspect of seasonality may now be included in the model development.

2.2 Linear, Multiple Season Model

This model is essentially the same as the single-season model except each term is allowed to vary seasonally. The shorthand equation is:

$$\text{MIN } [\sum_{i}^{Q} \sum_{k}^{N} (A_{ik} - \sum_{j}^{F} X_{jk} \cdot R_{ijk})] \qquad (6)$$

where k is the number of seasons and the other variables are the same as in equation (2).

In the multiple-season model, the standing crop (S_{ik}), is treated as a decision variable (actually a state variable), much the same as the number of herbivores (X_{jk}). This is necessary so that the model may allocate the entire remaining standing crop after grazing at the end of one time increment to the initial standing crop of the next time increment ($S_{i,k+1}$). This allocation to the range is forced by the appropriate constraints (see Section 2.5). For consistency and greater ease in comparing different model formulations, the standing crop is considered as a decision variable in the single-season models as well as the multiple-season models. Since the standing crop (S) is a function of itself and the herbivores (X) of the previous season, it may be expressed in terms of the herbivores and resubstituted back into the formulation so that (S) the standing crop drops out of the objective function. This is advantageous, since it cuts down on the number of decision variables being calculated in the deterministic models. Substitution becomes a necessity in the stochastic models since S becomes a random variable and random varibles are not permissible in an objective function. The standing crop may then be solved for after the herbivores (x) are calculated.

A further refinement of the overall deterministic model formulation is discussed next.

2.3 Quadratic Models

Since the botanical composition of a herbivore's diet often reveals a strong preference for rare plant species, a greater emphasis on allocating the major forage species can be placed in the formulation by squaring the deviations or difference terms in the objective function:

$$MIN \left[\sum_{i}^{Q} \sum_{k}^{N} (H \cdot U_{ik}(S_{ik} + G_{ik})(1 - L_{ik}) - t_k \sum_{j}^{F} X_{jk} \cdot C_{jk} \cdot P_{ijk})^2\right]. \quad (7)$$

This way, when the proportional composition of a herbivore's diet differs appreciably from the proportional composition of the range, it causes the value of the objective function to change quadratically; it changes linearly in the previous linear formulations of (5) and (6). Thus, in order to minimize the objective function (7), greater importance is placed on selecting herbivores whose diets are proportionally more in balance with the dominant available forage species or groups.

This formulation is similiar to a least squares regressions model in that the square of the differences between available and utilized forage is minimized. A least-squares method is used to choose m and b to minimze the sub-2 vector norm:

$$||y||_2 = MIN \left[\sum_k |y_k - mx_k + b|^2\right]$$

where y_k represents the k^{th} observation, m is the slope of the line and b is the y intercept. It is used in regression models because the optimal solution of the two unknowns, m and b, can be solved through two simultaneous equations without the need of costly matrix manipulations. Yet, it is general enough to use for a variety of curves and particularly applicable to data with a great deal of error. However, in the forage allocation optimization problem, the second order formulation of (7) greatly increases the complexity of the model by making it nonlinear and appreciably more difficult to solve by requiring specially formulated algorithms.

The quadratic model is, however, an excellent way to smooth out the functional objective in a multi-season model. For example, a linear multi-season model might find that the functional objective function can be minimized by allowing its entire value or discrepancy between available herbage and utilized forage to occur all at once in one of the seasons. Certainly such results are not realistic. By use of the quadratic model the functional objective value can spread out over all seasons making the results of such a model more applicable even though the magnitude of the objective function may be considerably larger.

Another method of smoothing the objective function while still retaining the simplicity of the linear model is presented below. This is to minimize the largest absolute value of the objective functional over all seasons expressed as:

$$MIN \left[\underset{1 \leq k \leq 3}{MAX} \left[\left| \sum_{i}^{Q} \sum_{k}^{N} A_{ik} - \sum_{j}^{F} X_{jk} \cdot R_{ijk} \right| \right] \right] \Longleftrightarrow MIN\ Q'$$

subject to two additional constraints unique to this smoothed formulation, which are as follows:

$$A_{ik} + Q' \geq \sum_{j}^{F} X_{jk} \cdot R_{ijk}$$

$$A_{ik} - Q' \leq \sum_{j}^{F} X_{jk} \cdot R_{ijk}.$$

The deterministic model formulation may now be weighted. This is considered in the next section.

2.4 Weighted Objective Functions

In the linear and quadratic models discussed above, the objective function makes no distinction between allowing a difference between available herbage and grazed forage to occur in either major or minor plant groups. However, it may be preferable to allow such differences, when they happen, to occur in the minor rather than the major plant groups. This can be accomplished by weighting the objective function components with the allowable available herbage. This way when a difference must occur between an available plant group and its respective grazing requirement, the objective function is penalized less for allowing a difference to occur in the minor plant groups as compared to the more dominant ones. The weighting function, W_{ik}, is:

$$W_{ik} = U_{ik} (S_{ik} + G_{ik})(1 - L_{ik}) \tag{8}$$

which is a function of the available herbage, A_{ik}, without the constant H.

The use of such a weight function (8), which is proportional to the allowable available herbage of each plant group, promotes an increased usage of the major plant groups. Previously, a difference existed between the available and grazed plants in the absence of weighting. The degree of difference in utilization of the major plant groups as a result of weighting is a function of the range of values of the weighting function. The range of the function corresponds to the difference between its largest values, the value associated with the dominant plant group, and the smallest value, or the value associated with the most minor plant group. The weighting function (8) is perhaps the simplest possible, and represents a proportional range of values, for its range is directly proportional to the range of availability of the plant groups. This simplest weighting function is also the most logical choice for the decision maker for it places greater emphasis on utilizing the most abundant plant groups. If the function (8) proved not to be effective, the range utilization may be increased through the use of a quadratic or exponential weighting function such as:

$$(W_{ik})^2 = (U_{ik} (S_{ik} + G_{ik})(1 - L_{ik}))^2 \tag{9}$$

or:

$$e^{W_{ik}} = e^{U_{ik} (S_{ik} + G_{ik})(1 - L_{ik})}. \tag{10}$$

These alternative weighting functions can result in quadratic and exponential increases in the range of the weighting function over the proportional

weighting function (8). These weighting functions all result in considerably greater utilization of the major plant groups if such plant groups are not being already utilized fully or to a degree satisfactory to the resource manager.

This management tool, the weighting function (8), has a cost associated with its use. Namely, the benefit of the tool as seen through increased usage of the major plant groups is associated with a decrease in overall utilization in all plant groups combined. This decrease in overall utilization of the available herbage has an uncertain effect on the resulting change in animal numbers. Total animal numbers may increase or decrease. Such a change in animal numbers is a function of their diet preferences and intake rates. It is important to note though, that a decrease in overall utilization of herbage as a result of weighting the objective function, must necessarily result in a decrease in the total number of animal unit equivalents in contrast to animal numbers. However, total animal numbers may be increased as a result of a larger increase in say pronghorn antelope over that of a corresponding decrease in bison; the total number of animal unit equivalents has decreased.

The bounds within which the objective function formulations may operate must be established. These constraints are discussed in the next section.

2.5 Constraints

Five types of constraints are used in the model.

The first constraint insures that tractable, non-negative solutions are calculated. An example would be in placing a bound on the herbivore decision variables, or:

$$B_{jk} \leq X_{jk} \leq Z_{jk} \tag{11}$$

The system of constraints in (11) yields $2 \cdot F \cdot N$ constraints, where F and N correspond to the maximum values assigned to j and k, respectively.

A second constraint, used in the seasonal models, prohibits seasonal increases in herbivores to guard against untractable solutions that would require transporting herbivores from one area to another:

$$X_{jk} \geq X_{j(k+1)} \tag{12}$$

which results in an additional $F \cdot (N-1)$ constraints. Since herbivore requirements as well as available herbage may vary considerably from season to season, the system of constraints in (12) would be primarily responsible for major differences between the allowable available herbage and the grazed forage. In some instances, as when reproduction occurs, this constraint would be relaxed.

A third constraint represents the Law of Conservation of Mass, or a state biomass balance equation for the multiple-season models. It is expressed as:

$$S_{i(k+1)} = H(S_{ik} + G_{ik})(1 - L_{ik}) - t_k \sum_{j}^{F} X_{jk} C_{jk} D_{ijk}. \tag{13}$$

It simply requires the model to allocate all of the remaining herbage of each plant group after grazing in season k to the initial standing crop (S) of season k+1. Recall that the standing crop (S) is also a decision variable as are the herbivores (X) and that each must be calculated. The system of constraints (13) yields $Q \cdot (N-1)$ constraints, where Q and N correspond to the maximum assigned values of i and k, respectively.

A fourth constraint is incorporated into the model framework to help maintain the site. It is:

$$M_k \leq \sum_{i}^{Q} (H(S_{ik} + G_{ik})(1 - L_{ik}) - t_k \sum_{j}^{F} X_{jk} \cdot C_{jk} \cdot D_{ijk}) \geq 0. \qquad (14)$$

The system of constraints (14) insures, within the confidence of the estimated and predicted parameters, that the land will have at least a specified minimal level of herbage (M_k) after grazing has occured in the k^{th} season. The system of equation (14) yields N constraints, corresponding to the range of seasons (k).

A fifth constraint insures that, within the confidence of the parameters, overgrazing cannot occur on the range. It is a necessary constraint because the gain in standing crop (G) drops out of the objective function since it is not a function of either of the decision variables (S) or (X). The overgrazing constraint is expressed as:

$$H \cdot U_{ik}(S_{ik} + G_{ik})(1 - L_{ik}) \geq t_k \sum_{j}^{F} X_{jk} \cdot C_{jk} \cdot D_{ijk}. \qquad (15)$$

The system of equations (15) yields $Q \cdot N$ constraints corresponding to the number of plant groups and season respectively.

The various systems of constraints (11), (14), and (15) yield for the single-season model a range of:

$$(Q + 1) \text{ to } (Q + 2 \cdot F + 1)$$

constraints. There are T + Q decision variables. The system of constraints (11), (12), (13), and (14) yield for the multiple-season models:

$$((F + Q + 1) \cdot N) + (Q \cdot (N - 1))$$

$$\text{to}$$

$$((3 \cdot F + Q + 1) \cdot N) + (Q \cdot (N - 1))$$

constraints.

A summary of the deterministic model formulations and deterministic constraints is presented in Table A1.

The Fundamental Theorem of Linear Programming (Luenberger 1973) states the optimal solution is such that the number of decision variables minus the

Table A1. Summary of deterministic model formulations and deterministic constraints.

Objective Functions

Model	Model Description					Constraints
1	: Linear	(Exponent=1),	Single season	(N=1),	Non-weighted : $W_{ik} = 1$	I, IV, V
2	: Linear	(Exponent=1),	Single season	(N=1),	Weighted : W_{ik} = weight function	I, IV, V
3	: Linear	(Exponent=1),	Multiple season	(N>1),	Non-weighted : $W_{ik} = 1$	I, II, III, IV, V
4	: Linear	(Exponent=1),	Multiple season	(N>1),	Weighted : W_{ik} = weight function	I, II, III, IV, V
5	: Quadratic	(Exponent=2),	Multiple season	(N>1),	Non-weighted : $W_{ik} = 1$	I, II, III, IV, V
6	: Quadratic	(Exponent=2),	Multiple season	(N>1),	Weighted : W_{ik} = weight function	I, II, III, IV, V

Shorthand Formula $\quad \mathrm{MIN}[\sum_i^Q(\sum_k^N(A_{ik} - \sum_j^F X_{jk} \cdot R_{ijk})^{\text{Exponent}} \cdot W_{ik}]$

Expanded Formula $\quad \mathrm{MIN}[\sum_i^Q(\sum_k^N(H \cdot U_{ik}(S_{ik} + G_{ik})(1 - L_{ik}) - t_k \sum_j^F X_{jk} \cdot C_{jk} \cdot D_{ijk})^{\text{Exponent}} \cdot W_{ik}]$

where W_{ik} or the weight function $= U_{ik}(S_{ik} + G_{ik})(1 - L_{ik})$

Constraint Constants

B_{jk} = Minimum allowable number of herbivore j at stage k

Z_{jk} = Maximum allowable number of herbivore j at stage k

M_k = Minimum allowable plant herbage remaining after grazing of stage k (kg)

Deterministic Constraints

I	$B_{jk} \leq X_{jk} \leq Z_{jk}$	Reasonable stocking limits ($2 \cdot F \cdot N$ constraints possible)
II	$X_{jk} \geq X_{j(k+1)}$	No seasonal increase in herbivores ($F \cdot (N-1)$ constraints)
III	$S_{i(k+1)} = H(S_{ik} + G_{ik})(1 - L_{ik}) - \frac{t_k}{H} \sum_j^F X_{jk} \cdot C_{jk} \cdot D_{ijk}$	Biomass balance equation: remaining standing crop of last season is fully realized in next season ($Q \cdot (N-1)$ constraints)
IV	$M_k \leq \sum_i^Q (H(S_{ik} + G_{ik})(1 - L_{ik}) - t_k \sum_j^F X_{jk} \cdot C_{jk} \cdot D_{ijk})$	Site maintenance constraint (k constraints)
V	$H \cdot U_{ik}(S_{ik} + G_{ik})(1 - L_{ik}) \geq \sum_j^F X_{jk} \cdot C_{jk} \cdot D_{ijk}$	Overgrazing constraint ($Q \cdot N$ constraints)

Model Coefficient Description

Shorthand Formulae

A_{ik} = Total allowable available herbage of plant group i at beginning of stage k

X_{jk} = Total number of herbivore j during stage k

R_{ijk} = Total grazing requirement of herbivore j for plant group i during stage k

Subscripts

i = plant group 1 to Q (5)
j = herbivore species 1 to F (4)
k = stage 1 to N (4)

Expanded Formulae

U_{ik} = Allowable use of plant group i at stage k (a proportion)

S_{ik} = Standing crop to be solved for of plant group i at beginning of stage k (kg ha^{-1})

G_{ik} = Additional gain in the standing crop of plant group i during stage k (kg ha^{-1})

L_{ik} = Loss in standing crop of plant group i during stage k (a proportion of S_{ik})

H = Land area in hectares (ha)

C_{jk} = Consumption rate of herbivore j during stage k (kg d^{-1})

D_{ijk} = Relative preference of herbivore j for plant group i during stage k (proportion)

t_k = Number of days in stage k (d)

number of constraints is equal to the number of zero-valued decision variables. Thus, the seemingly large number of constraints is required to insure that the model allocates to all the herbivores on the range.

Since many of the variables used in the model formulations above have a distribution with a mean and a variance, the variance about the mean needs to be incorporated into the formulation. With the mean and variance (or covariance) so included, the element of chance becomes important. This topic is discussed in the next section.

3.0 STOCHASTIC FORMULATIONS

Through use of chance constraints formulation (Charnes and Cooper 1959, 1962) the level of probability at which the constraints are satisfied may be set. The general chance constrained model is expressed as :

$$\text{MINIMIZE } f[\underset{\sim}{c}^T, \underset{\sim}{x}]$$

$$\text{subject to } P[A\,x \leq b] \geq {}_i \tag{16}$$

where the unsubscripted P is the probability, α_i is a vector of specified probabilities, superscript T refers to the transpose of the vector or matrix, and some or all of the elements in A, b, and c are random variables. The single-season model constraint:

$$P[\sum_{j}^{N} A_{ij} \cdot x_j \leq b_i] \geq \alpha_i \tag{17}$$

means that it may be violated some of the time, but it can be violated at most $100(1-\alpha_i)\%$ of the time. In this approach, the "exact" or deterministic constraints are replaced by their probabilistic counterparts. Equation (16) might be considered a poor model if the constraints are permitted to be violated even a very small percentage of the time. Some would argue that the cost of violating a constraint should be incorporated directly into the objective function in the form of a loss or penalty function (See Section 3.3). Since it is often extremely difficult to quantify a priori the cost of failing to satisfy a given constraint, one must generally be content with a probabilistic confidence-type statement of the constraint as shown above in (17). Chance-constraints represent "intentions" or policies of management rather than "hard-and-fast" rules. Thus, they represent the bounds within which management would like to operate "most of the time" rather than "all of the time" (Kirby 1970).

3.1 Formulation of Chance Constraints

The procedure of chance constrained programming is to reformulate the problem:

$$\text{OPTIMIZE } f[\underset{\sim}{c}^T, \underset{\sim}{x}]$$

$$\text{subject to } P[\underset{\sim}{A}\,\underset{\sim}{x} \leq \underset{\sim}{b}] \geq \tag{18}$$

$$\underset{\sim}{x} \geq 0$$

to a deterministic equivalent by converting the constraint into legitimate linear programming constraints (Bracken and McCormick 1968; Charnes and Cooper 1963; Hahn and Shapiro 1967; Hiller and Lieberman 1967; Meier et al. 1973).

Assume that for the i^{th} constraint the A_{ij}'s are independent normal random variables with means:

$$\overline{A_{i1}}, \ldots, \overline{A_{in}}$$

and variances:

$$VAR[A_{i1}], \ldots . VAR[A_{in}].$$

Then the i^{th} constraints' mean is:

$$\bar{u}_i = \sum_j^F \bar{A}_{ij} \cdot x_j \tag{19}$$

which is normally distributed with a variance:

$$VAR[u_i] = \sum_j^F VAR[A_{ij}] \cdot x_j^2. \tag{20}$$

Subtracting and dividing both sides of the constraint by the mean (19) and variance (20) respectively the constraint becomes:

$$P\left[\frac{\sum_j^F A_{ij} \cdot x_j - \bar{u}_i}{(VAR[u_i])^{1/2}} \le \frac{b_i - \bar{u}_i}{(VAR[u_i])^{1/2}}\right] \ge \alpha_i.$$

Since the A_{ij}'s are assumed to be normally distributed, the term:

$$\frac{\sum_j^F A_{ij} \cdot x_j - \bar{u}}{(VAR[u_i])^{1/2}}$$

is normally distributed with a mean of zero and variance of one. This means that:

$$P[A_{ij} \cdot x_i \le b_i] = CDF\left[\frac{b_i - \bar{u}_i}{(VAR[u_i])^{1/2}}\right] \tag{21}$$

where CDF represents the Cumulative Distribution Function of the standard gaussian distribution.

Let $K\alpha_i$ be a standard normal value such that:

$$CDF(K\alpha_i) = \alpha_i \tag{22}$$

then the statement:

$$P[\sum_j^F A_{ij} \cdot x_j \le b_i] \ge \alpha_i \tag{23}$$

is realized if and only if:

$$\frac{b_i - \bar{u}_i}{(\mathrm{VAR}[u_i])^{1/2}} \geq K\alpha_i . \tag{24}$$

This yields the following nonlinear constraint:

$$\bar{A}_{ij} \cdot x_j + K\alpha_i \left(\sum_j^F \mathrm{VAR}[A_{ij}] \cdot x_j^2\right)^{1/2} \leq b_i \tag{25}$$

which is the deterministic equivalent to the constraint of (18). If:

$$v_i = K\alpha_i \left(\sum_j^F \mathrm{VAR}[A_{ij}] \cdot x_j^2\right)^{1/2} = K_i \cdot \mathrm{SE}[u_i]$$

where SE is the standard error, then:

$$\sum_j^F \bar{A}_{ij}\, x_j \leq b_i - v_i \tag{26}$$

and the original stochastic problem (18) with the chance constraint (25) has the deterministic equivalent of:

$$\begin{aligned} &\text{OPTIMIZE } F(\underset{\sim}{c}^T, \underset{\sim}{x}) \\ &\text{subject to } \underset{\sim}{A}\,\underset{\sim}{x} \leq \underset{\sim}{b} - \underset{\sim}{v} \\ &\underset{\sim}{x} \geq 0 \end{aligned} \tag{27}$$

Uncertainty in the b vector can also be chance constrained under the same argument. Its components are assumed to be normally and independently distributed, with a known mean b_i and variance $\mathrm{VAR}[b_i]$ (Kirby 1970). Even with the simplifying assumption that random variables are mutually independent, the structure of the constraints is redefined from that of a linear structure to one of nonlinear structure (27), yet the objective function is still linear. This increases the complexity of the problem as well as the time required to solve it.

As an example of how a deterministic constraint is transformed into a chance constraint, the overgrazing chance constraint system is developed below. The deterministic model assures that overgrazing cannot occur only within the model, for the model assumes that all the variables are known with complete certainty. To account for this type of uncertainty, a system of overgrazing chance constraints that utilizes the means and variances of these random variables is derived from the deterministic system of constraints (15). The system of overgrazing chance constraints is expressed as:

$$H\, U_{ik}(S_{ik} + G_{ik})(1 - L_{ik}) - k_U((H\, S_{ik})^2 \cdot VAR[U_{ik}])^{1/2}$$
$$- k_{UG}(H^2 \cdot VAR[U_{ik} \cdot G_{ik}])^{1/2} - k_{UL}((H\, S_{ik})^2 \cdot VAR[U_{ik} \cdot L_{ik}])^{1/2}$$
$$- k_{UGL}(H^2 \cdot VAR[U_{ik} \cdot G_{ik} \cdot L_{ik}])^{1/2} \geq t_k \sum_j^F X_{jk} \cdot C_{jk} \cdot D_{ijk} \tag{28}$$
$$+ k_{CD}((t_k \cdot X_{jk})^2 \cdot VAR[C_{jk} \cdot D_{ijk}])^{1/2}$$

where k_U, k_{UL}, k_{UG}, k_{UL}, k_{UGL}, and k_{CD} in (28) are constants of standard normal deviates and represent the level of probability or the $(1 - \alpha_i)$ fractile that the constraint will be satisfied on the rangeland.

3.2 Multivariate Distributions

It may be unreasonable to assume the simplifying assumption that the A_{ij}'s are mutually independent. Consumption by a herbivore may not be independent of its preference for a plant group just as the standing crop may not be independent of an additional gain in the standing crop or even a loss due to decay, trampling, or shattering. In fact, such assumptions are certainly violated and, therefore, any statistical confidences associated with the constraints are less certain than what one could directly infer.

In such cases where there are significant non-zero covariances, they should be incorporated in the chance constraint formulation. Consider then the problem of dependent, multivariate, and normal A_{ij}'s (see notation conventions in Appendix I; the following discussion uses standard statistical and optimization notation). For convience we use matrices and vectors to define the random variable:

$$\underset{\sim}{a}_i = (A_{i1}, \ldots, A_{in})^T \tag{29}$$

the distribution of which has a mean of:

$$\bar{\underset{\sim}{a}}_i = (\bar{A}_{i1}, \ldots, \bar{A}_{in})^T \tag{30}$$

and variance:

$$VAR[\underset{\sim}{a}_i] = \begin{bmatrix} VAR[A_{i1}] & \cdots & COV[A_{i1}, A_{in}] \\ \vdots & & \vdots \\ COV[A_{in}, A_{i1}] & \cdots & VAR[A_{in}] \end{bmatrix} . \tag{31}$$

Then, let the i^{th} constraint be defined as:

$$u_i = \underset{\sim}{a}_i^T \cdot \underset{\sim}{x} \tag{32}$$

where:

$$\underset{\sim}{x} = (x_i, \ldots, x_n)^T . \tag{33}$$

The random variable u, is normally distributed with a mean:

$$\bar{u}_i = \bar{a}_i^T \cdot x \tag{34}$$

and variance:

$$VAR[u_i] = x^T \cdot VAR[a_i] \cdot x. \tag{35}$$

The i^{th} constraint of the chance-constrained programming problem:

$$P[u_i \geq b_i] \geq \alpha_i \tag{36}$$

can be manipulated as in the previous procedure by substituting $a_i^T \cdot x$ for $\sum_j^F A_{ij} \cdot x_j$

and $x^T \cdot VAR[a_i] \cdot x$ for $\sum_j^F VAR[a_{ij}]x^2$ to obtain:

$$\bar{a}_i^T \cdot x = K_i (x^T \cdot VAR[a_i] \cdot x)^{1/2} \geq b_i. \tag{37}$$

Of course, a "price" must be paid for the use of random variables in the formulation of constraints. That price is discussed next.

3.3 Penalty Functions

As discussed previously, when a constraint has a finite non-zero probability of violation, it may be desirable to incorporate the cost of violating the constraint directly into the objective function through use of a penalty function. Such a penalty function provides a measure for adjoining an additional cost of violation. Since the penalty functions are non-linear, an additional source of non-linearity is introduced. With the previous chance constrained formulation, the penalty functions may be introduced for violating the chance constraints and adjoined to the expected penalty costs as an additional term to the original objective function (Sengupta 1972).

Consider the linear constraint:

$$e_i = a^T \cdot x - b_i \leq 0 \tag{38}$$

where, the decision vector x has to be chosen before the actual values of A_{ij} and b_i are known, which can cause in actuality, a non-zero value for e_i. Since the constraint (38) need not be satisfied exactly, there is a penalty cost of $K_i \cdot f(e_i)$. There are many versions of the penalty function that can be applied here.

The most biologically significant approach would be to incorporate the mean and variance of e_i directly into the objective function. Consider that even though the constraints are satisfied within the model to prohibit overgrazing, overgrazing does still occur in actuality because the demands for forage, availability of forage, and grazed forage are not *a priori* known with

complete certainty. Actually then, grazing within the specified limits occurs only Q of the time instead of all of the time, or overgrazing occurs (1− Q) of time. As a consequence of overgrazing occurring at a level e_i for plant group i (1− Q) of the time, management policy would incur a penalty cost specified by a penalty function, f(e,A,G). This way, when an amount e_i is over-allocated in a five-year period for example, the penalty function would allow management to allocate $0.2 \cdot e_i$ less per annum. So, perturbations to the range system through overgrazing at times can be compensated for at other times. Thus, an optimal combination of herbivores can still be solved for based on the best estimates (expected values) of herbivore demand and available forage. However, estimating the amount of overgrazing and its distribution is not a trivial matter. The overgrazing constraint, used in the chance-constrained formulations (38), can be expressed as:

$$e_i = a_i - \sum_j^F x_j \cdot R_{ij} \leq 0 \qquad (39)$$

where e_i is the degree of actual overgrazing. Adjoining the penalty cost function to the orginal linear or quadratic functional of the chance-constraint model, gives the following deterministic nonlinear program:

$$\text{MIN } [\sum_i^Q \sum_k^N (A_{ik} - K(H^2 \cdot \text{VAR}[e_i])^{1/2} - \sum_j^F X_{jk} \cdot R_{ijk})] \qquad (40)$$

subject to the chance constraints in the following section.

The constant $k_{\text{VARIABLES}}$ in the chance constraints reflects the system's sensitivity to perturbation through overgrazing and is inversely related to the constant K used in the objective function.

3.4 Application of Chance Constraints

In the chance constraint formulations, the parameters C, G, L, D, and U are considered random variables while t and H are constants and S is in actuality a random variable. It is used as a decision variable whose value is forced by a probabilistic confidence type statement within the constraints which are used to substitute S out of the objective function.

The constraints are formulated under the simplifying assumption that the random variables are mutually independent and distributed normally. Such assumptions are not biologically supported, however, nor is there sufficient data to specify the covariance structure between consumption or preference of a group of herbivores and a group of plants. Knowledge of the covariance structure of these and other relationships would be required in order to not assume mutual independence.

The expected value between the products of two random variables is:

$$E[Y \cdot Z] = E[Y] \cdot E[Z] + \text{COV}[Y,Z] \qquad (41)$$

where E is the expectation operator or mean (Mood et al. 1963; Hahn and Shapiro 1967) and COV is the covariance operator. An approximation to the variance of their product is:

$$\begin{aligned} VAR[Y \cdot Z] &= E[Z]^2 \cdot VAR[Y] + E[Y] \cdot VAR[Z] \\ &+ 2\, E[Y] \cdot E[Z] \cdot COV[Y,Z] - (COV[Y,Z])^2 \\ &+ E[(Y - E[Y])^2 \cdot (Z - E[Z])^2] \qquad (42) \\ &+ 2 \cdot E[Z] \cdot E[(Y - E[Y])^2 \cdot (Z - E[Z])] \\ &+ 2 \cdot E[Y] \cdot E[(Y - E[Y]) \cdot (Z - E[Z])^2]. \end{aligned}$$

If the random variables are mutually independent, then the COV[Y,Z] term drops out of the expected value expressions in (42), and the variance becomes precisely:

$$VAR[Y \cdot Z] = E[Y]^2 \cdot VAR[Z] + E[Z]^2 \cdot VAR[Y] + VAR[Y] \cdot VAR[Z]. \qquad (43)$$

It would appear from equation (42) that the variance of the product of two random variables would be larger as a result of a covariance structure. However, this is not generally the case. Since a known covariance structure is also used to determine a more accurate mean or expected value of the product of dependent random variables, the variance of the mean of such a product is usually less than if there is no significant correlation between the random variables as in equation (43).

In general, there are no simple exact formulas for the variance of the product of correlated random variables, only approximations. Furthermore, one can readily see both the increased complexity and increased sources of nonlinearity which are added to the formulation through usage of a covariance structure. Because of non-linearity due to least square techniques and accounting for uncertainty in random variables, specialized solution algorithms are required to solve these formulations iteratively (Himmelblau 1972).

A summary of the stochastic model formulations, the chance constraints and variance formulations is presented in Table A2.

A total of 12 model formulations have been presented in Tables A1 and A2. Table A3 is a summary of model types and model components. It delineates the objective function components of the 12 models as to whether they are non-weighted or weighted and whether they are linear or quadratic. Those with penalty functions are also shown. Table A3 also denotes those constraints for models 1 through 12 which are deterministic or stochastic according to the seasonality of the specific model formulation.

3.5 Linear Programming Under Uncertainty

Chance constraints and penalty functions, both of which are deterministic equivalents to a stochastic problem, are not the only means to account for uncertainty. A stochastic linear program such as Linear Programming Under

Table A2. Summary of stochastic model formulations, chance constraints and variance formulations.

Objective Functions

Model						
7	: Linear	(Exponent=1),	Single season (N=1),	Without penalty function (K=0),	Non-weighted	(W_{ik} = 1)
8	: Linear	(Exponent=1),	Multiple season (N>1),	With penalty function (K>0),	Weighted	(W_{ik} = weight function)
9	: Quadratic	(Exponent=2),	Multiple season (N>1),	Without penalty function (K=0),	Non-weighted	(W_{ik} = 1)
10	: Quadratic	(Exponent=2),	Multiple season (N>1),	With penalty function (K>0),	Non-weighted	(W_{ik} = 1)
11	: Quadratic	(Exponent=2),	Multiple season (N>1),	Without penalty function (K=0),	Weighted	(W_{ik} = weight function)
12	: Quadratic	(Exponent=2),	Multiple season (N>1),	With penalty function (K>0),	Weighted	(W_{ik} = weight function)

All models use constraints I, II, IIIB, IVB, VB

Shorthand Formula $$\text{MIN}[\sum_i^Q(\sum_k^N(A_{ik} - K(S_{ik}^{\,2} \cdot \text{VAR}[e_i])^{\frac{1}{2}} - t_k \sum_j^F X_{jk} \cdot R_{ijk})^{\text{Exponent}} \cdot W_{ik}]$$

Expanded Formula $$\text{MIN}[\sum_i^Q(\sum_k^N(H(U_{ik}(S_{ik} + G_{ik})\ (1 - L_{ik}) - K(S_{ik}^{\,2} \cdot \text{VAR}[e_i])^{\frac{1}{2}} - t_k \sum_j^F X_{jk} \cdot C_{jk} \cdot D_{ijk})^{\text{Exponent}} \cdot W_{ik}]$$

where the weight function = $U_{ik}(S_{ik} + G_{ik})\ (1 - L_{ik}) - K(S_{ik}^{\,2} \cdot \text{VAR}[e_i])^{\frac{1}{2}}$; and K is the $(1 - \alpha_i)$ fractile

e_i = penalty function variance due to overgrazing as a result of uncertainty in the random variables (U_{ik}, S_{ik}, G_{ik}, L_{ik}, C_{jk} and D_{ijk})

Chance Constraints

IIIB $$S_{i(k+1)} = H(S_{ik} + G_{ik})\ (1 - L_{ik}) - k_G(\text{VAR}[G_{ik}])^{\frac{1}{2}} - k_L((S_{ik})^2 \cdot \text{VAR}[L_{ik}])^{\frac{1}{2}} - k_{GL}(\text{VAR}[G_{ik} \cdot L_{ik}])^{\frac{1}{2}}$$
$$- \frac{t_k}{H}(\sum_j^F X_{jk} \cdot C_{jk} \cdot D_{ijk} + k_{CP}((t_k \cdot X_{jk})^2 \cdot \text{VAR}[C_{jk} \cdot D_{ijk}])^{\frac{1}{2}})$$

IVB $$M_k \le \sum_i^Q(H(S_{ik} + G_{ik})\ (1 - L_{ik}) - k_G(H^2 \cdot \text{VAR}[G_{ik}])^{\frac{1}{2}} - k_L((H \cdot S_{ik})^2 \cdot \text{VAR}[L_{ik}])^{\frac{1}{2}} - k_{GL}(H^2 \cdot \text{VAR}[G_{ik} \cdot L_{ik}])^{\frac{1}{2}}$$
$$- t_k(\sum_j^F X_{jk} \cdot C_{jk} \cdot D_{ijk} + k_{CD}((t_k \cdot X_{jk})^2 \cdot \text{VAR}[C_{jk} \cdot D_{ijk}])^{\frac{1}{2}}))$$

VB $$\sum_i^Q H \cdot U_{ik}(S_{ik} + G_{ik})\ (1 - L_{ik}) - k_U((H \cdot S_{ik})^2 \cdot \text{VAR}[U_{ik}])^{\frac{1}{2}} - k_{UG}(H^2 \cdot \text{VAR}[U_{ik} \cdot G_{ik}])^{\frac{1}{2}} - k_{UL}((H \cdot S_{ik})^2$$
$$\cdot \text{VAR}[U_{ik} \cdot L_{ik}])^{\frac{1}{2}} - k_{UGL}(H^2 \cdot \text{VAR}[L_{ik} \cdot U_{ik} \cdot G_{ik}])^{\frac{1}{2}} \ge t_k \sum_j^F X_{jk} \cdot C_{jk} \cdot D_{ijk} + k_{CP}((t_k \cdot X_{jk})^2$$
$$\cdot \text{VAR}[C_{jk} \cdot D_{ijk}])^{\frac{1}{2}})$$

where k_G, k_L, k_U, k_{UG}, k_{UL}, k_{GL}, k_{CP} and K_{UGL} are the fractiles corresponding to $(1 - \alpha_i)$ of each of the respective random variables or their products.

Variance Formulations

$$\text{VAR}[G_{ik} \cdot L_{ik}] = E[G_{ik}]\ \text{VAR}[L_{ik}] + E[L_{ik}]\ \text{VAR}[G_{ik}] + \text{VAR}[G_{ik}] \cdot \text{VAR}[L_{ik}]$$

$$\text{VAR}[C_{jk} \cdot D_{ijk}] = E[C_{jk}]\ \text{VAR}[D_{ijk}] + E[D_{ijk}]\ \text{VAR}[C_{jk}] + \text{VAR}[C_{jk}] \cdot \text{VAR}[D_{ijk}]$$

$$\text{VAR}[U_{ik} \cdot G_{ik}] = E[U_{ik}]\ \text{VAR}[G_{ik}] + E[G_{ik}]\ \text{VAR}[U_{ik}] + \text{VAR}[U_{ik}] \cdot \text{VAR}[G_{ik}]$$

$$\text{VAR}[U_{ik} \cdot L_{ik}] = E[U_{ik}]\ \text{VAR}[L_{ik}] + E[L_{ik}]\ \text{VAR}[U_{ik}] + \text{VAR}[U_{ik}] \cdot \text{VAR}[L_{ik}]$$

$$\text{VAR}[U_{ik} \cdot G_{ik} \cdot L_{ik}] = E[U_{ik}]\ \text{VAR}[G_{ik} \cdot L_{ik}] + E[G_{ik}]\ E[L_{ik}]\ \text{VAR}[U_{ik}] + \text{VAR}[U_{ik}] \cdot \text{VAR}[G_{ik} \cdot L_{ik}]$$

Table A3. Summary of model types and model components.

Model	OBJECTIVE FUNCTION					CONSTRAINTS			
	Linear		Quadratic		Penalty	Single Season		Multiple Season	
Number	Non-Weighted	Weighted	Non-Weighted	Weighted	Function	Deterministic	Stochastic	Deterministic	Stochastic
1	X					X			
2		X				X			
3	X							X	
4		X						X	
5			X					X	
6				X				X	
7	X								X
8		X			X				X
9			X						X
10			X		X				X
11				X					X
12				X	X				X

Uncertainity (LPUU) is one such alternative (programming in this instance refers to mathematical programming rather than to a computer code). LPUU is not a deterministic equivalent, but uses random variables directly. Within one objective function, the program minimizes error due to undercertainty that would result in overgrazing or undergrazing. One of the great advantages of such a program is that it is a much simpler way to deal with the means and variances of random variables and their products. Also, is it not necessary to assume normality. In fact, virtually any distribution can be easily managed by the program. However, LPUU is limited in that all random variables must be confined to the b vector of the $\underset{\sim}{A}\underset{\sim}{x}=\underset{\sim}{b}$ constraints. However, the grazing allocation models dealt with herein must contend with random variables in the A matrix as well.

3.6 Stochastic Dynamic Programming

Dynamic programming is an optimization method that is well suited for determining management policies for systems described by nonlinear or stochastic difference equations (Bellman and Dreyfus 1962; Dreyfus and Law 1977; Hall and Day 1977; Nemhauser 1966). A sequence of decisions, which in turn yields a sequence of situations, is sought that minimizes (or maximizes) some measure of value, e.g., utilization of annual production of range forage. Dynamic programming can be used for problems of the form:

$$H_n(S_n) = \underset{V_n,\ldots,V}{\mathrm{MAX}} \left[\sum_i^N R_i(S_i,V_i) \right]. \tag{44}$$

In equation (44), the state variables at each time are related by:

$$S_{i+1} = S_i + F(S_i,V_i) \tag{45}$$

where F is the rate of change of the state variable S, the standing crop. The function R_i is the return to the criterion function on the i^{th} time interval, corresponding to the herbivore's diet preference or utilization of the available forage.

The basis of the dynamic programming algorithm is Bellman's Principle of Optimality which states:

> "An optimal policy has the property that whatever the state and initial decisions are, the remaining decisions must constitute an optimal policy with regard to the state resulting from the first decision (Bellman and Dreyfus 1962)."

Applying this principle to the above equations (44) and (45), we obtain:

$$H_k\ (S_k) = \underset{V_k}{\mathrm{MIN}}[R_k(S_k,V_k) + H_{k+1}\ (S_{k+1})] \tag{46}$$

and:

$$S_{k+1} = S_k + F(S_k,V_k). \tag{47}$$

Although $R_k(S_k,V_k)$ is a specific function and its value is therefore known, the values of the function, H_k and H_{k+1}, are not known. Thus, equation (46) cannot be solved directly. Instead, the equations are solved recursively starting with $H_n(S_n)$, the final stage, and working backward to $H_1(S_1)$, initial stage. Since the value of $R_n(S_n,V_n)$ is known, the value of $V_n^*(S_n)$ that minimizes (or maximizes) the equation:

$$H_n(S_n) = \underset{V_n}{\mathrm{MIN}}\ R_n\ (S_n,V_n) \tag{48}$$

can be determined analytically or numerically.

Dynamic programming can also be used to determine an optimal management policy for a stochastic range forage production system through the use of stochastic transfer functions. If the available forage (state variable S) has the expected value m with a probability p_i, then the recursive dynamic programming equation (46) becomes:

$$H_n(S_n) = \underset{V_n}{\mathrm{MAX}}\ (E[R(S_n,V_n)] + \sum_{i-1}^{N} p_i H_{n+1}(u_i)). \tag{49}$$

Equation (49) can be solved by recursively calculating values of $H_n(S_n)$ and $V_n{*}D(S_n)$ and by using (47) and (48), starting with n=N and ending with n=1 as in the deterministic model. An algorithm is available that can handle deterministic random variables with independent probabilities and random variables with transition probabilities. However, a major drawback of dynamic programming is dimensionality. Depending upon whether optimization problems are set up allotment by allotment or district by district, and depending on how many animal species and time periods in the year are involved, dimensionality can expand tremendously.

Another alternative to chance constraints is stochastic dynamic programming. A readily available algorithm for stochastic dynamic programing works with random variables. It does not have the disadvantages associated with chance constraints; it does, however, require that the number of state variables must be kept small. That is if, for example, eight decision variables are used in the model (herbivores) then the number of resources should be limited to plant groups (warm-season grasses, etc.) rather than plant species.

4.0 OPTIMIZATION ALGORITHMS

There are numerous solution algorithms available. Hence, a revised simplex algorithm, LINPRO, and LPUU, a stochastic linear programming solution code have been selected for our linear forage allocation problems. Lemke's complimentary pivot method is one of the better quadratic programming codes available; it is appropriate for use with deterministic models 3 and 6. The Colorado State University Dynamic Programming algorithm, CSUDP, is useful in a dynamic programming consideration of the model. The Generalized Reduced Gradient solution package, GRG, one of the better nonlinear programming algorithms and the Fiacco-McCormick (1964) Penalty Function method (SUMT) are candidates for solving the chance-constrained formulations and for solving the penalty-function formulations of the model.

Each algorithm is specifically developed for a particular type of mathematical programming problem and would, therefore, be a poor choice as a general problem solving algorithm. Thus, different algorithms may be used most efficiently on different problem formulations. Different algorithms can be evaluated for each of the distinct models for each of the different cases, e.g., linear, quadratic, dynamic, nonlinear and stochastic formulations.

The amount of coding required for various problem formulations for different algorithms is formidable. It is therefore desirable to convert the formulation to standard matrix--vector form for inputs. Then the necessary subroutine calculations can be made with predeveloped and pretested matrix operation algorithms. This reduces the chance for errors in the calculations and coding and it observes the original problem formulation as is developed herein.

5.0 SUMMARY

Several models and variations of them have been presented as a proposed method of forage allocation decision-making. These models range from the very simple linear model (with several inherent simplifying assumptions) to the more complex quadratic models, dealing with chance constraints and penalty functions (with fewer inherent simplifying assumptions). The models need to be converted into standard matrix form and tested against each other, against different solution algorithms, and for tractable results.

We consider the linear and quadratic single-season models drastic over-simplifications of forage allocation decision-making on grazinglands, but such models are a means of testing our conceptualization of the range-use efficiency problem. The quadratic weighted, multiple season model appears to be the most tractable since it accounts for seasonality and differences in availability of different plant groups in ways that can make more efficient and consistent use of the range. All the models proposed require extensive testing. The linear and quadratic deterministic models can be solved for exact optimal solutions, unlike the formulations with non-linear chance constraints, where solutions are approximated with more complex solution algorithms. Thus, the deterministic linear and quadratic models can be used as the basis for testing the conceptualization of the models for realistic and tractable results. Once these models have withstood extensive testing and likely improvements are added and retested, then realistic chance constraints and penalty functions can be added. At that time, the models should be evaluated for their realism. The solution algorithms used to solve them must also be tested for reliability in obtaining optimal solutions. Eventually a model (or specific models for specific cases) of forage allocation based on sound biological reasoning will be proposed as a reliable method of dealing with the range forage allocation problem.

Only when the true biological constraints of the grazing system are recognized and then satisfied through proper management schemes, can grazinglands be fully and properly utilized as a resource.

CHAPTER B

A CRITICAL REVIEW OF PROPER USE FACTORS

ABSTRACT

Though mention is made of the Proper Use Factor (PUF) in the literature and several range management textbooks, published lists of PUF values for herbivore and plant combinations are scarce. Scarcer still are published accounts of the formulation of PUF values. This report considers the definition of proper use factors and the way in which they are subject to variation. Two examples of the use of proper use factors, other than for judging the quality of a range, are shown. One example calculates the diet botantical composition for a herbivore when the proper use factor and the range composition is known. The other example calculates the range composition from known proper use factors and diet botantical composition. The methodology of PUF value formulation is discussed. The lack of appropriate rules and guidelines for proper use factor formulation is not consistent with sound scientific or ecological principles. The distinction and the relationship between the proper use factor and the allowable use factor is discussed. The differences between two compilations of PUF values, one done in the late 1950's, the other in 1979, are presented. The general conclusion is that over the intervening period of time, the PUF values for many plant species have been lowered. Although PUF value formulation is lacking, because they have been complied for plants in many regions, they may be useful as guidelines in different aspects of forage allocation analysis. But, because of the nature in which PUF values are arbitrarily formulated, they should be used with caution. A range-region effort is needed to establish PUF values for each subregion. Such an effort should be based on a thorough survey of clipping and grazing studies and it should include complete documentation on the methodology used in the formulation of PUF values.

CHAPTER B

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1.0 PROPER USE FACTOR (PUF)

The purpose of this chapter is to examine the occurrence of Proper Use Factors (PUF) in the scientific literature, the apparent change in PUF values for the same regions over some 20 years and the application of PUF values to the development of optimization models for forage allocation.

1.1 Proper Use Factors in Forage Allocation Optimization Study

Reference is made to the "Optimization Models for Forage Allocation to Combinations for Large Herbivores for Grazingland Situations" Progress Report of November 1979 (Janisz et al. 1979). In that report, Table 1 presents alternative model formulations and appropriate constraints developed for the optimization of forage allocation. There are six models presented in both shorthand formulation and expanded formulation. Model number 1, the expanded formula, is shown below:

$$\mathrm{MIN}\Big(\sum_i (HU_i(S_i + G_i)(1 - L_i) - D\sum_j x_j C_j P_{ij})\Big) \qquad (1)$$

where H is the number of hectares in the study area, S is the standing crop at the beginning of the grazing season, G is the gain in the standing crop during the season, L is the loss in the standing crop due to decay and shattering and trampling, D is the number of days in a specified season, C is the herbivore daily intake rate, and P is the relative preference of each herbivore for a specific plant group. The variable x represents the decision variable or the number of herbivores of the j^{th} species to graze a given plant group i on a given range. In this formulation, the variable U is included and represents the Allowable Use Factor. This last variable, U, is the major concern of this report. Its inclusion in the model structure is necessary to insure the maintainance of the range herbage. Since U is entered as a proportion (or percent), its position in the model structure insures that the herbage available to the grazing animal is less than is physically present on the range. This means that the manager can adjust this parameter to allow maximum utilization of a forage species and still leave enough of the plant tissue at the end of the grazing season to enable that species to recover. He may in instances of poor quality rangeland or where overgrazing has occured in the past, set U very low, thereby enabling the range to recover.

As can be seen, the use factor is an intergral part of the conceptualization of the model problem and of the model framework itself. As will be noted below, scientific information on U is not abundant. A related, but different concept, i.e., the PUF, has been used by resource management agencies for 40 years and may provide valuable insights into U.

For the moment, the proper use factor will be considered and allowable use taken up again later in this chapter.

1.2 Definition of Proper Use Factors

A Proper Use Factor may be defined as the percentage use that is made of a forage species under proper management of the range as a whole (Stoddard et

al. 1975). Another definition of the Proper Use Factor is given by Sampson (1952). He says it is the percentage weight (sometimes height) at which the available plant species are grazed when the range is properly used. He equates this measure with the palatability factor. Sampson (1952) further states that proper utilization of the range is the degree of annual removal of forage that will maintain or improve the grazing capacity of a range unit over a series of years. He says this term is synonymous with that of proper use. It may be interpreted in the following way. If a PUF for a given plant species is set at 30%, it indicates that that plant will have 30% of its current annual aboveground production removed by the end of the grazing season, again under proper management.

In summary, the value of a proper use factor is defined for a specific situation, i.e., on a given range composed of certain plants in certain abundances <u>and</u> grazed by a specific herbivore <u>and</u> in a given season.

1.3 Variation in PUF Values

Proper use factors are reported usually according to herbivore or herbivore group. The problem with such distinctions is that herbivore species are rarely present alone on the rangeland; they are present, at least during some parts of the year with other herbivore species. The PUF value for one species of herbivore grazing one species of plant is usually different for a second herbivore species grazing the same forage species. Such considerations cause variaton in PUF values. That variation is discussed next.

Stoddart et al. (1975) list several reasons for variability in PUF's. They are:

* The plants associated with any given plant species and their relative abundance can vary that plant's PUF.

* The species of animal allowed to graze a given plant species can vary the PUF.

* The season of the year affects moisture, nutrient and sugar concentration in plant parts and thereby causes the PUF to vary.

* The climatic variations from year to year can affect, for example,the moisture in the plant and consequently alter the PUF for that species on that range.

* Past grazing of a plant can cause variation in PUF's since regrowth is more tender and hence, more attractive.

* PUF values vary due to undefined local conditions as shown by differential grazing of two plants of the same species growing side by side.

* Animal familiarity or unfamiliarity with forage plants can cause PUF variation.

With an understanding of what a PUF value is and the way in which it may vary, the method of PUF formulation is taken up next.

2.0 FORMULATION AND USE OF PUF VALUES

It must be remembered that a PUF is a function of plant production and animal species grazing that plant. If a range has a composition of only one plant species (a uniform environment) and is grazed by only one herbivore, the PUF for that range could be determined and applied readily to managing the range resource. Like so many concepts in the natural sciences, however, the PUF is an ideal. Physics has the frictionless surface and the black box concept, neither of which may be truely realized or found in nature. Both, however, serve as a starting point or basis for abstract formulation. The same may be said of the ideal gas law found in chemistry and several other fields of scientific endeavor (e.g., biophysics, biochemistry, physiology, medicine). It is an abstract, a concept from which simplified but real, applicable methodologies and techniques can be formulated.

The PUF is applied not to the uniform environment of a single-plant species range, nor to an environment with small vegetational gradients in it. Rather, it is applied to a many-species range or what may be termed a patchy environment (MacArthur and Pianka 1966), an environment that has stands or spots of one type of herbage, bare ground, different forage species stands, etc. Also, this patchy environment is not utilized by one herbivore, but perhaps several. Extensive literature (Chapter E) exists which shows that the large herbivores, the concern of this modelling study, select particular forage plants while leaving other available plants alone. Such utilization of a heterogeneous (patchy) environmental mosaic in a course-grained manner (Pianka 1974) means, in the real world, that a number of PUF values must be used, one for each herbivore or group of herbivores over each forage species.

For the purposes of this discussion, we disregard seeded pastures where the predominant plant cover would be all one species. Too, we exclude the circumstance where a cow will be unaware of a patch of clover among the grass it is eating. The latter case would be an example of a fine-grained environment that would not elicit a different response of the herbivore as it is encountered (Emlen 1973). The former is a case where the heterogeneity of the environment is removed and the subsequent response of the herbivore altered. The degree of patchiness of the environment bears directly on the response of the herbivore and on the amount of time the herbivore spends in or on the patches. The unaware cow above probably does not actively seek out patches of forb or browse and may actively avoid the latter. A more generalized grazer, like a goat, would not avoid any particular patch but spend more time on browse or forb patches than would the cow.

When the environmental pulses of seasonality are considered, a third dimension to the above must be added. When one considers that in some instances the large herbivores compete for forage (Abrams 1975), the result is a hodge-podge of PUF values which provide for a very noisy and intractable system from a management viewpoint: that is, if PUF values are applied to managing a rangeland and herbivore system at all.

2.1 The Concept

As mentioned previously, the PUF is dependent on the forage plant species composition, the herbivore involved, and the season. Or conceptually:

PUF = f(forage plants, herbivores, season) (2)

where f is read "a function of." This conceptual model is still incomplete, however. Abiotic factors other than season must be considered as well. Climate certainly is one of these factors. Proper use of sagebrush may be quite different in eastern California as opposed to northern Utah; the proper use in each case dependent on yearly rainfall, relative insolation and so forth. Edaphic status of the rangeland also influences proper use. Soil nutrient content, type, substrate and others need to considered. Slope and aspect are also important. Herbivores other than big game and livestock make use of forage species as well. Fructivorous insects and rodents affect plant production by using plant seeds and fruits while other insects, rodents, and lagomorphs consume other plant parts. The effects of these herbivores, if considered on a single-organism scale, are small compared to say, the effects of cattle stocked at moderate densities, but considered collectively, their presence on a range is of consequence.

Equation 2 now becomes:

PUF = f(forage plants, large herbivores, season, edaphic conditions, climate, small herbivores) (3)

Of course other components could be added to Equation 3. From the above though, it should be obvious that the PUF is dependent on a number of variables.

2.2 Calculations Using PUF Values

Correctly formulated PUF values may be employed by management agencies in ways other than judging the level of proper use of a range. The exercises that follow are two such ways.

2.2.1 Calculating Diet Botantical Composition from Known Range Composition and PUF Values

Assume a hypothetical range composed of four plant species and the percent of each plant species on the range is known as is their PUF values:

Plant Species	Range Composition (%)	PUF (%)
A	30	50
B	25	20
C	35	40
D	10	80
	100	

The products of the range composition and the PUF values yields the proportion grazed of each of the plant species. The total of the proportions divided into each proportion separately yields the precent of each plants species in the diet. For plant species A the product of its range composition and its PUF is 1500. The total of the products for this example is 4200. the percent of species A in the diet is then 1500/4200 or 36%. For the entire range:

Plant Species	Range Composition (%)	PUF (%)	Product	Diet Composition (%)
A	30	50	1500	36
B	25	20	500	12
C	35	40	1400	33
D	10	80	800	19
	100		4200	100

As may be seen, the range composition column and the diet composition column sum to 100%. The numbers under the range composition column in actuality would be supplied by a vegetation survey method, e.g., SVIM. The PUF values would be extracted from tables maintained by the natural resource management agencies.

There are two provisos that should be considered when applying the above method of calculation. The first is that the rangeland under consideration be managed properly. If the land is being mismanaged the (constant) PUF values would not apply and the calculations would be meaningless. The second proviso is the understanding that the efficient use of a range may require that highly palatable plants, present sometimes in small percentages, would be overused in order for the more abundant but less palatable species be used up to the PUF value assigned to them.

2.2.2 Calculating Range Compoistion From Known Diet Botanical Composition and PUF Values

Very often diet botanical composition of herbivore diets is reported in the literature. However, usually the botanical composition of the range from which the diet information was taken is not reported. An application of PUF values may be used to remedy that situation. Since the reversal of the sequence of calcuations used in Section 2.2.1 does not yield the original range composition, a more laborious calculation must be used.

If a range is composed of i plants species and these plant species have PUF values of a_i and further if the botanical composition of the diet is c_i, then a system of equations may be set up in order to solve for b_i, the botanical composition of the range. For a given range the product of a single PUF value and a single value of percent botanical composition of the range divided by the sum of all such products yields the diet botanical composition:

$$(a_i \cdot b_i)/(\sum_i a_i\ b_i) = c_i. \tag{4}$$

Clearing the right side of equation (4) and multiplying both sides of the equation by the denominator gives:

$$a_i b_i - c_i \sum_i a_i b_i = 0. \tag{5}$$

Thus, in a situation with three plant species or groups the following equations would be found:

$$c_1a_1b_1 + c_1a_2b_2 + c_1a_3b_3 = a_1b_1$$
$$c_2a_1b_1 + c_2a_2b_2 + c_2a_3b_3 = a_2b_2 \quad (6)$$
$$c_3a_1b_1 + c_3a_2b_2 + c_3a_3b_3 = a_3b_3.$$

Rearranging the system of equations in (6) according to the method outlined above gives:

$$c_1a_1b_1 - a_1b_1 + c_1a_2b_2 + c_1a_3b_3 = 0$$
$$c_2a_1b_1 + c_2a_2b_2 - a_2b_2 + c_2a_3b_3 = 0 \quad (7)$$
$$c_3a_1b_1 + c_3a_2b_2 + c_3a_3b_3 - a_3b_3 = 0.$$

Further rearrangement shows the equations in terms of sums of known coefficients (a_i and c_i values) times the unknowns (the b_i values):

$$[(c_1a_1 - a_1)]b_1 + [c_1a_2]b_2 + [c_1a_3]b_3 = 0$$
$$[c_2a_1]b_1 + [(c_2a_2 - a_2)]b_2 + [c_2a_3]b_3 = 0 \quad (8)$$
$$[c_3a_1]b_1 + [c_3a_2]b_2 + [(c_3a_3 - a_3)]b_3 = 0.$$

The system of equations in (8) can be put into matrix equation form:

$$\begin{bmatrix} (c_1a_1) - a_1, c_1a_2, c_1a_3 \\ c_2a_1, (c_2a_2) - a_2, c_2a_3 \\ c_3a_1, c_3a_2, (c_3a_3) - a_3 \end{bmatrix} \begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}. \quad (9)$$

The matrix equations can be solved readily on a digital computer to secure the values of b_i, i.e., the botanical composition of the range.

Consider the following simple range example:

Plant Species	PUF (%)	Diet Composition (Proportion)	Range Composition (%)
A	4	.0635	b_1
B	35	.5596	b_2
C	24	.3810	b_3

The b_i values can be derived as follows using the PUF values as proportions:

$$\frac{0.4b_1}{0.4b_1 + 0.7b_2 + 0.6b_3} = .0635$$

$$\frac{0.7b_2}{0.4b_1 + 0.7b_2 + 0.6b_3} = .5556$$

$$\frac{0.6b_3}{0.4b_1 + 0.7b_2 + 0.6b_3} = .3810$$

Rearrangement, setting the right-hand side to zero as in (7), (8), and (9) results in:

$$\begin{aligned} -0.3746b_1 + 0.0444b_2 + 0.0381b_3 &= 0 \\ 0.2222b_1 - 0.3111b_2 + 0.3333b_3 &= 0 \\ 0.1524b_1 + 0.2667b_2 - 0.3714b_3 &= 0. \end{aligned} \qquad (10)$$

However, there are an infinite number of nontrivial solutions to this system of equations. We can replace one of the equations with a known relationship involving the three unknowns and obtain a valid solution. We know that the botanical composition of the range sums to 1.0 thus $b_1 + b_2 + b_3 = 1.0$. Therefore, replacing the third equation with this known relationship gives:

$$\begin{aligned} -0.316b_1 + 0.147b_2 + 0.126b_3 &= 0 \\ 0.148b_1 - 0.441b_2 + 0.222b_3 &= 0 \\ 1b_1 + 1b_2 + 1b_3 &= 100. \end{aligned} \qquad (11)$$

Solving this system of equations gives:

$$\begin{aligned} b_1 &= 0.10 \\ b_2 &= 0.50 \\ b_3 &= \underline{0.40} \\ & 1.00 \end{aligned}$$

This calculation of course is dependent on the two known vectors of diet botanical composition and PUF values. In practice, if these vectors aren't well known, then erroneous values of b_i may result. For example, if in any given year on any given range one particular plant species is rare but makes up say 60% of a herbivore's diet (whereas in normal years it is much less), the method of determining range composition shown above would over estimate that plant species' contribution to the range composition. The provisions mentioned in Section 2.2.1 apply here as does one other. That is, the herbivores must be grazing the forage species somewhat uniformly, neither greatly preferring nor avoiding a particular plant. Should this provision not apply, then use of the above method to determine range composition would not be appropriate.

2.3 The Methodology

The scientific literature has been searched for information on a variety of topics, the object being to establish parameter mean values and their variances in order to construct and operate optimization models. There is a remarkable scarcity in the literature on the methodology used in the formulation of PUF values. This is an odd and unfortunate situation, since one of the salient features of the scientific method is that once results and

methods are reported, they can be reproduced and verified by other workers. The two sources of PUF values detailed in the next section report values, but nowhere do they explain, expound, or list how one is to formulate a PUF.

Several individuals have ostensibly made use of the PUF in their work. Nelson (1977) used the concept of proper use in his examination of the work of Smith (1965). Smith addressed himself to a "utilization standard" of a single plant species when determining the trade-offs in herbivore stocking rates. In neither instance however, is the method for PUF determination described though both authors present models in which PUF values play a major role.

Earlier work by Cook (1954) and Hopkin (1954), who reworked Cook's data, consider the economic benefits of using PUF values in stocking sheep and cattle on a Utah range. Both assume PUF values, allude to their formulation, but do not say explicitly how they were determined. There are other examples in the literature where PUF values are assumed or formulated somehow, or both, but the procedure is not mentioned. Hormay and Fausett (1942) give several criteria, based on appearance, for judging the condition of annual-grass ranges that have been grazed. If the grazing has been at the proper level,

* adequate mulch should be present and the average stubble height should be about 2 inches,

* the remaining vegetation should have a patchy, mottled appearance,

* a sufficient forage should be left to hide squirrel mounds, livestock trails, etc. when viewed from a distance of 20 feet,

* vegetation under shrubs and around rocks should be only lightly cropped,

* a large proportion of seed heads of the less preferred grass species should remain ungrazed.

Note should be made here that the above method is quite subjective, relying as it does on the appearance of the range.

Sampson (1952) says some 35 to 50% of the current volume (by weight) of herbage should remain at the end of the grazing season. That standard is for rangeland sites in fair to good condition. For lower quality sites, he suggests that about 60% of the current forage volume and 25% of the flower stalks should be left. These of course are general rules-of-thumb.

These techniques of estimating proper use of a range and by inference the PUF values of the plant species on that range, lack repeatability. The observer must be the same in every instance, else the range condition will not be estimated the same way each time.

Wooton (1908) is apparently the only author who has set down in print the methodology for PUF formulation. He says,

"...it is possible by looking at a range to tell how it has been treated. The number and kinds of range weeds, the kinds and abundance of grasses, the condition of the shrubbery, the amount and character of the erosion features, all taken together with an appreciation of the common or typical condition of the (range), tell the story of what the range has been, and hence what it may be again by proper treatment (emphasis added)."

That is to say, a manager simply determines PUF values by looking at the range.

2.4 The Relationship of the Allowable Use Factor (AUF) to the PUF

While the PUF is ostensibly a management tool, the Allowable Use Factor or AUF is a number sometimes used to measure a plant's physiological response to grazing. It is the amount of above-ground plant parts which can be grazed and still allow the plant to recover. AUF formulation is supposed to be derived from clipping studies (c.f. for example Biswell and Weaver 1933, Jameson 1963, McCarty and Price 1942, and Aldous 1930).

Some suggested utilization levels of selected grass and forb species compiled from the scientific literature are presented in Table B1. These values may be interpreted as allowable use levels from which AUF values can be derived. The transition between the allowable level of use and the percentage or proportional AUF however is cloudy at best, as there seems to be a lack in the literature of detailed methods to make the transformation. Note too that Table B1 does not show any seasonality for reporting the utilization values, a fact reflected from the literature. The most deficient attribute in the studies reported in Table B1 though is that they were undertaken without the complication of the presence of other plants. Recall that the rangeland is not a homogeneous environment as it is implicitly considered in these studies, but a patchy environment. This makes the utilization values in Table B1 little more than interesting numbers if the goal is to use to the fullest extent the mosaic that is the rangeland.

There are fewer utilization values reported in the scientific literature for browse or shrub species than for grass and forb species. Some representative numbers are given in Table B2. The same criticism of the studies used to determine the values in Table B1 may also be applied to the values in Table B2.

The relationship between the PUF and the AUF is somewhat hazy, but several precepts may be elucidated. Generally, it may be stated that an AUF for a given plant species is greater than the PUF for that species. If the range is comprised of a single plant species, the AUF and the PUF would have the same value; if the manager required full utilization of the herbage for herbivore production. But, as mentioned previously, the range is a mosaic of vegetation and as a consequence, the AUF values and the PUF values differ. It may also be stated that for efficient use of the range, some highly palatable forage plants which are present in small numbers will have PUF values greater than AUF values, meaning these plants are sacrificed.

Table B1. Compilation of suggested use standards for selected grass and forb species.

SPECIES	LOCATION	USE STANDARD	REMARKS	AUTHORITY
Bouteloua gracilis	Southwestern U.S.	clipped to within 2 in. (5.1 cm) of ground	at that height, 72% of total height and 55% of volume was removed.	Crafts 1938a
Hilaria belangeri	Arizona	stubble height of 3 inches (7.6 cm)		Campbell and Crafts 1938
Festuca arizonica	Arizona	stubble height of 5 inches (12.7 cm)		Crafts 1938b
Bouteloua curtipendula	Arizona	stubble height of 4 inches (10.2 cm)		
Agropyron spicatum	Northwestern U.S.	3 inch (7.6 cm) stubble height		Pickford and Reid 1942a
Festuca viridula	Northwestern U.S.	3 inch (7.6 cm) stubble height		
Poa secunda	Northwestern U.S.	3 inch (7.6 cm) stubble height		
Deschampsia caespitosa	Northwestern U.S.	3 inch (7.6 cm) stubble height	value is for meadows dominated by tuffed hairgrass	Pickford and Reid 1942b
Bouteloua gracilis	Central Great Plains, U.S.	1.75 inch (4.4 cm) stubble height	value is for good growth years	Costello and Turner 1944
Buchloe dactyloides	Central Great Plains, U.S.	1.75 inch (4.4 cm) stubble height	value is for good growth years	
Bouteloua gracilis	Central Great Plains, U.S.	1.25 inch (3.2 cm) stubble height	value is for poor growth years	Costello and Turner 1944
Buchloe dactyloides	Central Great Plains, U.S.	1.25 inch (3.2 cm) stubble height	value is for poor growth years	
Agropyron desertorum	Central Colorado	2 inch (5 cm) stubble height		Johnson 1959
Agropyron intermedium	Central Colorado	3.9 inch (10 cm) stubble height		
Agropyron smithii	Arizona - New Mexico	3.3 inch (8.4 cm) stubble height		Parker and Glendening 1942
Agropyron smithii	Eastern Montana	1 to 2 inch (2.5 to 5 cm) stubble height		Holscher and Woolfolk 1953
Bromus inermis	Central Colorado	4 inch (10.2 cm) stubble height		Johnson 1959
Carex filifolia	Eastern Montana	1 to 2 inch (2.5 to 5 cm) stubble height		Holscher and Woolfolk 1953
Elymus juncens	Central Colorado	3 inch (7.5 cm) stubble height		Currie and Smith 1970
Stipa comata	Eastern Montana	2 inch (5 cm) stubble height		Holscher and Woolfolk 1953
Hilaria belangeri	Arizona - New Mexico	1.6 inch (5 cm) stubble height		Parker and Glendening 1942
Koeleria cristata	Arizona - New Mexico	2 inch (5 cm) stubble height		Parker and Glendening 1942

Table B2 . Compilation of suggested use standards for selected browse species.

SPECIES	LOCATION	USE STANDARDS	REMARKS	AUTHORITY
Purshia tridentata	Northeastern California	40% current growth should be left		Hormay 1943
Ceanothus sanguineus	Northern Idaho	25% current growth should be left	Value is for spring and/or fall cropping; such use during summer damages the plant.	Young and Payne 1948
Amelanchier alnifolia	Northern Idaho	35% current growth should remain		
Fraxinus americana	Southeastern Texas	75% current growth should remain		Lay 1965
Ilex vomitoria	Southeastern Texas	50% current growth should remain		

In short, there is a conceptual linkage between AUF values and PUF values: the two ideas should mesh and provide useful management tools to private and public regulators. In fact however, the real world link between the AUF and PUF is not at all well established. And, AUF formulation methodologies are lacking in the literature and range science textbooks; the same state as is found for PUF values. The presence of lists in government agency files of AUF's and PUF's indicates that at some time and place persons in the agencies involved gave thought to the problem. However, even in the agency reports there is no satisfactory discussion of the data or information base from which the lists were developed.

How, then, are PUF or AUF values formulated? Apparently, they are established by "rule-of-thumb" or intuition. As such, little credence can be put in any PUF value, a fact that does not help management agencies in promulgating their policies, nor does it help the rancher or the conservationist prudently use and share the range resource.

With this in mind, some differences in PUF values for the same plants are detailed in the next section.

3.0 DIFFERENCES BETWEEN TWO COMPILATIONS OF PROPER USE FACTORS

Only two sources of PUF values have been found in the course of this study, both unpublished. The first, hereafter referred to as the "new" compilation, was supplied by the Denver Service Center of the Bureau of Land Management (BLM). It lists the plant species and Allowable Use Factors and Proper Use Factors, as of November, 1979, for the Vernal Utah District of the BLM according to spring, summer, fall, and winter seasons. The animals considered in this listing are antelope, cattle, mule deer, Rocky Mountain elk, domestic sheep, and Rocky Mountain bighorn sheep. The other source is an extensive compilation of Proper Use Factors made by G. M. Van Dyne and H. G. Fisser during the late 1950's (unpublished). (See Appendix II entitled "Classification of Range Plants: Proper Use Factors.") This tabulation, referred to hereafter as the "old" compilation, made use of several BLM reports, Soil Conservation Service multiliths, and some research station reports, which are referenced. The geographic regions considered therein were the Northwest states, the Southwest states, and the Great Plains region of the United States. That tabulation did not consider individual animal species but the two aglomerates of "cattle and horses," and "sheep and goats," presumably because cattle and horses, and sheep and goats have similar foraging characteristics.

3.1 An Example of Changes Over 20 Years

Have the PUF values for plant species been changed over time? In order to answer that question, the two sources of PUF's were compared. (The mean value for the Great Plains region in the old tabulation and the yearlong value in the new tabulation were used for this comparison.) By subtracting the new value from the old, the change in magnitude of the value, if any, could be determined. In each case, the magnitude of the difference was recorded by animal-animal comparison and plant group comparison. The plant groupings according to shrubs, warm-season and cool-season grasses, and warm-season and cool-season forbs were made according to the information in Downton (1975), Kautz and Van Dyne (1978), Schuster and Garcia (1973), Sims et al. (1978), and Waller and Lewis (1979). The results are presented in Table B3.

3.1.1 Changes of Less than 5%

The least substantial changes between the old and new compilations are recorded in the plus or minus 5% column of Table B3. The greatest number of changes for the animal-to-animal comparison in this category is shown for the cattle versus cattle and horse pairing with 13 changes of less than 5%. The plant considerations showed 11 changes in the cool-season grasses plant group. Overall, there were 23 changes of less than 5% between the two PUF compilations.

3.1.2 Changes of Greater Than 5%

More substantial changes in the range of plus or minus 5 to 15% are shown in columns marked -(5 to 15) and +(5 to 15) in Table B3. The minus 5 to 15% range indicates that at a total of seven PUF values have been increased since

Table B3. The range of change in proper use factors for important plant groups by herbivore species or group. Numbers at the top of the columns refer to the range of the difference between the two PUF compilations. Numbers within the columns refer to the frequency of occurrence in that category.

	<-25				-(15 to 25)				-(5 to 15)				± 5				+(5 to 15)				+(15 to 25)				>+ 25				TOTALS			
	C-C,H[a)]	S-S,G	BHS-S,G	Category Total	C-C,H	S-S,G	BHS-S,G	Category Total	C-C,H	S-S,G	BHS-S,G	Category Total	C-C,H	S-S,G	BHS-S,G	Category Total	C-C,H	S-S,G	BHS-S,G	Category Total	C-C,H	S-S,G	BHS-S,G	Category Total	C-C,H	S-S,G	BHS-S,G	Category Total	C-C,H	S-S,G	BHS-S,G	Row Totals
Cool Season Grasses									1		2	3	5	3	3	11		3	3	6	3	1	2	6	3	5	2	10	12	12	12	36
Warm Season Grasses									1			1										1	1	2	1	1	1	3	2	2	2	6
Unclassified[b)] Grasses	1			1		1	1	2					1			1	1	1	2	4	1	3		4	1	3	3	7	5	8	6	19
Cool Season Forbs													1			1	3	1	1	5					2	5	5	12	6	6	6	18
Warm Season Forbs													2	1	1	4	2			2						2	2	4	4	3	3	10
Unclassified Forbs													2			2	2	1	1	4	1	1	1	3	1	4	4	9	6	6	6	18
Shrubs					1	1	1	3	3			3	2	2		4	3	3	4	10		2	3	5	2	4	3	9	11	12	11	34
Column Totals	1			1	1	2	2	5	5		2	7	13	6	4	23	11	9	11	31	5	8	7	20	10	24	20	54	46	49	46	141

a) C-C,H cattle compared with cattle and horses; S-S,G sheep compared with sheep and goats; BHS-S,G big horn sheep compared with sheep and goats.
b) unclassified refers to absence of plant species in the several references consulted (Downton 1975; Kautz and Van Dyne 1978; Schuster and Garcia 1973; Sims, Singh and Lauenroth 1978; Waller and Lewis 1979) for warm and cool season characteristics.

the Van Dyne and Fisser compilation, with a majority of the increases (5) in the cattle--cattle and horse comparison. In the plus 5 to 15% column, a total of 31 PUF values are shown to have been reduced over about 20 years, the majority of the reductions in the shrubs and cool-season grass plant groups. In this column, the animal-to-animal comparisons are very nearly the same as shown by the column totals of 11, 9 and 11. The column of minus 15 to 25% shows five instances of increased PUF values while the column marked <-25 shows only one PUF increase when the two compilations are compared. The column marked +(15 to 25)% shows a total of 20 instances of PUF values being decreased. It is noteworthy that no changes were recorded for either warm-season or cool-season forbs in this column. The greatest number of PUF value decreases over the time span between PUF compilations occurred in the greater than 25% range (the column labeled >+25), a total of 54, or 38% of all the changes. The animal--animal comparison of sheep versus sheep and goats showed the greatest number of changes in this category.

If the column for plus or minus 5% is ignored, it is of interest to note that 105 instances of change involved a decrease in the PUF values while only 13 show an increase. The basis for such a change should be examined in detail (see suggested studies under Conclusion).

3.2 Interpretation of the Change in Proper Use Factors

The major conclusion to be drawn from the above exercise is that PUF values have been decreased in a substantial number of instances between the times of the two compilations. This conclusion must be qualified, however. The old listing was an extraction of information which represented the means of several sources reporting PUF values for areas throughout the Great Plains region of the US while the Vernal Utah PUF values were formulated specifically for that BLM district. The data in the old tabulation were compiled on an animal aggregation basis while the new material reports PUF values by six specific animal species. Not every plant species on the Vernal list was represented in the Van Dyne and Fisser list, or if it was shown there, it was not listed for the Great Plains region.

These qualifications are important and they reduce the significance of the information presented in Table B3. As was noted earlier in this report, the methodologies for the formulation of PUF values appear to be entirely lacking from the scientific literature. Because of this lack and because of the seemingly arbitrary manner in which these numbers are raised and lowered, little credence can be attached to them or their use.

4.0 CONCLUSION

This chapter has detailed the concept, formulation, and expected use that can be made of the Proper Use Factor, PUF. The overall conclusion is that little if any credibility can be given to the PUF values or the AUF values on which the former are based owing to the fact that their formulation is subject to error and lack of repeatability.

In order for the concept of the PUF to gain scientific respectability, a thorough search of the literature is required, particularly for reports on grazing-intensity studies. Such studies, to be useful, would have had to include a list of the plants grazed (notice "plants" is plural, hence the study was carried out in a patchy environment), the level at which grazing was allowed to occur (light, medium, heavy), and the reports should include both qualitative and quantitative measures of proper use. Of course any studies undertaken in the future should also have the above items in the final report or paper.

Natural resource management agencies should undertake the establishment of PUF formulation methodologies and the dissemination of those methodologies.

As of the moment, any PUF values encountered, whether in Appendix II or in the literature or in the BLM computer printouts (e.g., as for Vernal, Utah), should be used with caution.

CHAPTER C

A CRITICAL REVIEW OF FORAGE INTAKE RATE

ABSTRACT

A survey of the literature on forage intake rates of large domestic and wild herbivores was undertaken in order to establish rates for use in optimization forage allocation models. Methods of measuring forage intake rates are discussed and mention is made of the disadvantages of using each method. Forage intake rates for the above mentioned herbivores are tabulated as intake $animal^{-1}day^{-1}$ and as intake per unit of metabolic body weight weight $animal^{-1}day^{-1}$. A considerable body of information exists on consumption rates derived from grazing trials for domestic sheep and cattle, but wildlife studies, and those for horses and burros are represented in the literature by conventional pen--feeding trials or absent altogether. Recommendations to remedy the absence of such information are made. Forage intake rates are presented for various conditions, but averaged overall and expressed as kilograms per animal per day are as follows: cattle, 7.5; sheep, 1.4; bison, 6.1; bighorn sheep, 1.6; pronghorn antelope, 0.8; deer, 1.9; elk, 4.5; horses, 7.1; and burros, 5.0. The mean live body weights in kilograms for the animals in these situations were 343.1, 55.6, 348.0, 62.1, 40.8, 66.9, 181.4, 378.3 and unspecified respectively. These intake rates and body weights result in the following relative intake rates expressed as percent body weight: cattle, 2.2; sheep, 2.2; bison, 1.7; bighorn sheep, 2.6; pronghorn antelope, 2.1; deer, 2.2; elk, 2.4; horses, 1.7; and since no body weight was specified for the one burro study cited, no intake rate as percent body weight could be calculated.

CHAPTER C

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1.0 INTRODUCTION

An article appearing in Science (Abelson 1980) points out that in the early part of the 1980's the cost of feedlot fattened beef cattle will rise while the profit to the owners of feedlots will decline. The decline in profits is regarded as a result of increased costs of transporting live and dressed cattle, increased world demand for grain which is used as feed for beef cattle and increased national demand for grain as an alternative fuel source (gasahol). The author further maintains that grain fed cattle require about 8 kilograms of feed to produce 1 kilogram of meat, while poultry and swine use about 2.5 kilograms of grain to produce 1 kilogram of meat. Abelson contends that this cattle inefficiency compared to swine and poultry, is caused by destruction of some of the grains' food value by the rumen microflora. One way to overcome this inefficiency is to make use of cattles' natural ability to use forage as food. Such a contention makes the study of forage allocation to, and forage intake rates of, large herbivores a timely undertaking.

As will be shown in the discussion that follows, forage intake varies, subject to the age of the foraging animal, the physiological state of the animal (pregnant, lactating, etc.), the nutrient content of the forage, the moisture content of the forage, the metabolism of the forage plants (C_3 or C_4) and the past history of the grazingland. Of course, forage intake is not dependent on any one of the above characteristics but on combinations of two or more of them. Methods of forage intake measurements are also presented and since half of the forage allocation optimization models we have developed require a measure of dispersion about the mean of a number of the variables and since the dispersion about a mean is due in part to error (and in part to chance), the error induced in measuring forage intake is discussed.

Reference is made to Chapter A. That chapter presented twelve optimization models which determine combinations of large herbivores that optimally utilize grazinglands. Model numbers 1 through 6 take the expanded form:

$$MIN[\sum_{i}^{Q}(\sum_{k}^{N}(H \cdot U_{ik}(S_{ik} + G_{ik})(1 - L_{ik}) - t_k \sum_{j}^{F} X_{jk} \cdot C_{jk} \cdot D_{ijk})^{Exponent} \cdot W_{ik})] \qquad (1)$$

where 1 through Q is the range of plant groups i, 1 through F is the range of herbivore species j, 1 through N is the number of seasons k. The exponents, in increasing orders of magnitude, cause the model to favor a combination of herbivores whose combined diet, in proportional composition, most resembles the proportional plant group composition of the range. The capability to weight the formulation is accomplished by W_{ik}. The available forage is expressed in terms of S the standing crop at the beginning of the season, G the gain in standing crop over the season, the allowable use U of plant species i, the size of the area under consideration H which is a constant and the complement of the loss L due to shattering, trampling and decay. The forage requirement is expressed as the number of days in the k^{th} season t multiplied by the diet preference D of the j^{th} herbivore in the k^{th} season for the i^{th} plant group. The decision variable X is the number of herbivores of each

species allowed to graze the range. The variable C, consumption or forage intake rate of the j^{th} species is a major concern of this report and is entered into the formulation as kilograms animal^{-1}day^{-1}.

We consider in our study the domestic herbivores cattle and sheep and those wild herbivores indigenous to the range during all or part of the year. Our purpose was to survey the literature on forage intake and ascertain rates of ingestion and the variances of these rates for use in the optimization models. Though we have compiled forage intake information from many sources, we realize our lists are not complete. The data presented, however, is representative of the information available and yields information necessary to establish the initial conditions for our models.

A term used extensively herein needs description. Metabolic body weight (MBW) is often used to describe the relationship between body size and the energy required to maintain that body. The concept was developed from the empirically realized surface-to-area law, which states that the heat given off by all warm blooded animals is directly proportional to their surface area (Maynard and Loosli 1969). That is, the volume of the body varies to the cube while the surface area varies to the square. The practice used by some investigators is to apply a decimal power to the body weight as a unit of reference. Brody (1945) and co-workers found that over many animal species, ranging in size from 0.02 kg to 4000 kg (mice to elephants), the 0.734 expondent best related body weight to basal metabolism. Kleiber (1947) used the power 0.756 to obtain the best fit for his data. Harris (1966), under the auspices of the National Research Council, has prepared an extensive list of weight and weight to the 0.75 power. The convention is to use the 0.75 exponent to relate body weight and metabolism, though Brody (1945) and Maynard and Loosli (1969) report values of 0.6 for dogs and 0.82 for mature rabbits and a reported range for the exponent in the literature of 0.62 to 0.70 for bird species. Cordova et al. (1978) report that there is a trend to express forage intake in terms of organic matter intake per kilogram of metabolic body weight.

The pertinence of this measure of intake is twofold. Firstly, the relationship between weight and weight to the three-quarter power is not linear; see Table C1 and Figure C1. As can be seen in Table C1, the increment for metabolic body weight between 50 and 100 (pounds or kilograms) is 12.8 while the increment between 950 and 1000 is 6.7. Figure C1 shows the relation between a curve of weight versus metabolic body weight and a line with a slope of one.

Secondly, the common animal-unit-month of animal stocking and productivity in range management is based on the 1000 pound cow--calf unit. A recent series of memos between the Bureau of Land Management (BLM), the National Cattlemens Association and the University of Nevada substantiate the use by the BLM of an 800 pound animal-unit-mouth for forage allocation in the State of Nevada. Of importance here is that a reduction (or increase) of 200 pounds does not mean a reduction (or increase) of the same magnitude in metabolic weight. Careful attention should be paid by resource management agencies to this distinction.

Table C1. The values of body weight and body weight to the three-quarter power.

BODY WEIGHT	$\left(\text{BODY WEIGHT}\right)^{0.75}$
1	1.00
50	18.80
100	31.62
150	42.86
200	53.18
250	62.87
300	72.08
350	80.92
400	89.44
450	97.70
500	105.74
550	113.57
600	121.23
650	128.73
700	136.09
750	143.32
800	150.42
850	157.42
900	164.32
950	171.12
1000	177.83

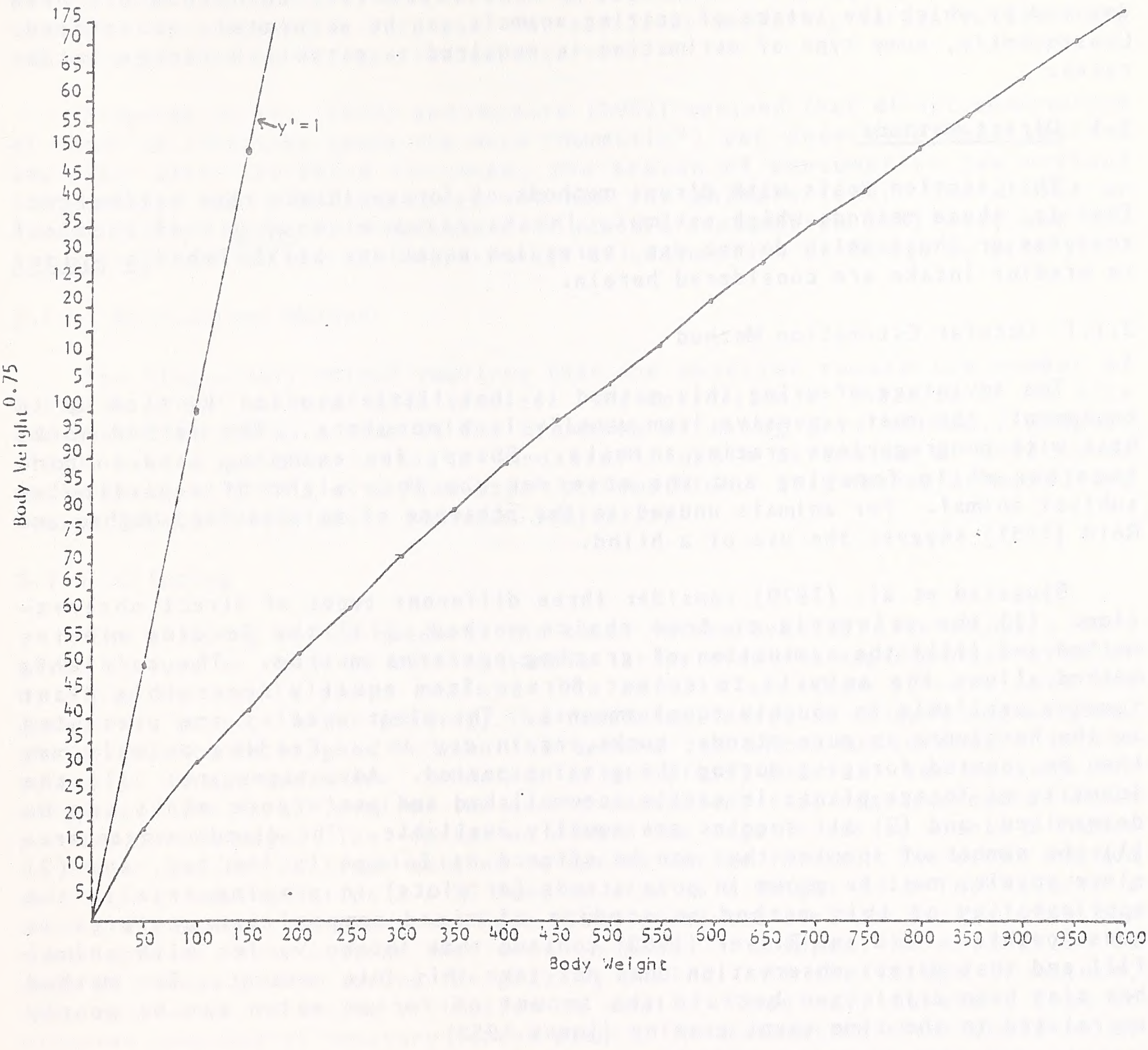

Figure C1. The relationship between body weight and body weight to the three-quarter power.

2.0 METHODS OF DETERMINING FORAGE INTAKE

There are several methods of determining forage intake rates for large herbivores. As Cordova et al. (1978) point out however, no method has been devised by which the intake of grazing animals can be accurately quantified. Consequently, some type of estimation is required to establish forage intake rates.

2.1 Direct Methods

This section deals with direct methods of forage intake rate estimation. That is, those methods which estimate intake rates without use of chemical analyses or those which do not use regression equations established a priori to predict intake are considered herein.

2.1.1 Occular Estimation Method

The advantage of using this method is that little capital is tied up in equipment; the most expensive item usually is binoculars. The method works best with nongregarious grazing animals. Sheep, for example, tend to band together while foraging and the observer can lose sight of a particular subject animal. For animals unused to the presence of an observer, Hughes and Reid (1951) suggest the use of a blind.

Bjugstad et al. (1970) consider three different types of direct observation: (i) the cafeteria or free choice method, (ii) the feeding minutes method and (iii) the evaluation of grazing patterns method. The cafeteria method allows the animals to select forage from equally accessible plant species available in roughly equal amounts. The plant species are presented to the herbivore in pure-stands, bunks, or in dry lot. Feeding animals may then be counted foraging during the grazing period. Advantages are: (1) the identity of forage plants is easily accomplished and preference ranks can be determined, and (2) all species are equally available. The disadvantages are: (1) the number of species that can be offered as forage is limited, and (2) since species must be grown in pure stands (or plots) in grazing trials, the applicability of this method to studies of mixed composition pastures is questionable. Hurd and Blaser (1962) contend that intake varies with animal fill and that direct observation does not take this into account. The method has also been criticized because the amount of forage eaten can be poorly correlated to the time spent grazing (Jones 1952).

The feeding-minutes method requires the observer to watch and time the grazing animal as it feeds on each plant. The contribution of each species to the diet is assumed to be proportional to the time spent grazing it. The disadvantage of this method is that with a scope or binoculars, it is difficult to distinguish between active grazing and mere nibbling (Bjugstad et al. 1970). Another approach was used by Kautz and Van Dyne (1978) in analyzing observational data on grazing of pronghorn antelope. They converted bite count data to a weight basis. They used data on the weight of 100 simulated bites hand-collected for each plant species. Thus, field data on percent bites was converted to percent weight.

The evaluation of grazing patterns technique requires background knowledge of grazing use on various range types during good conditions at

different times of the year. With that information, deviations from established grazing-use patterns show that desired plants have been grazed and have become rare. The grazing animal(s) then spend time searching for better forage and the observer notes that a quantity of forage plants has been removed. This method is very poor for precisely measuring forage intake rate and is dependent on an experienced observer.

Bjugstad et al. (1970) and Hubbard (1952) contend that direct observation of domestic livestock (note the word "domestic") can determine what species and plant parts are being consumed, the season of consumption (an obvious contention), where on the range and how the animals feed. The direct or ocular methods alone are inadequate to measure consumption precisely and are not appropriate at all for measurements of consumption of forage by wildlife.

2.1.2 Bite--Count Method

The bite--count method requires that the observer record the number of bites an animal takes of each species. The definition of the size of the bite and what constitutes a bite is the drawback of using this method. Reppert (1960) uses a quantity called a "mouthful" in his estimates of bite count while Sheppard (1921) uses "jaw wags" per mouthful. This method of measuring forage intake is obviously somewhat subjective.

2.1.3 Clipping

The clipping method measures the total forage available to animals on a given pasture or range by cutting sample strips over the experimental area or by clipping sample plots nearby. The animals are then allowed onto the pasture to graze. After grazing, the remaining forage is clipped and weighed, the difference in weights between the before and after measurements is the amount of forage consumed. Schneider et al. (1955) consider two methods for clipping. The first involves the use of convenient size cage exclosures which protect the herbage. The vegetation within the cage is cut to within 2 inches in height and the cuttings weighed to derive forage intake. The other method consists of mowing strips 3 x 30 feet in size to a height of 2 inches with a sickle bar mower. Garrigus and Rusk (1939) find two serious faults with the mower method. They contend that once an area is clipped, no estimation is made of forage growth during the grazing period. If the forage is mature, then this error in intake estimation is small. They say, however, that on pastures composed of immature forage plants, the estimation error could be as much as 10 percent. Their second criticism of this method is that the strips mowed may not be entirely representative of the whole pasture. This coupled with the forage growth error could, they say, result in more forage available at the end of the grazing period than at the beginning or negative consumption.

The direct methods discussed above all can be criticized as being too observer dependent or impractical under many rangeland conditions. Methods of indirect estimation of forage intake are discussed next.

2.2 Indirect Methods

Indirect methods of estimating forage intake rates typically involve some previous experimentation and determination in order to establish chemical

components in forage or feces or to develop mathematical relationships between pen--feeding studies and grazing trials.

2.2.1 Internal and External Indicator Ratio Methods

In order to use one of the ratio techniques to measure forage intake, two indicators are required; an internal indicator to estimate the indigestibility of the consumed forage and an external indicator, which is completely indigestible and used to determine fecal output (Reid and Kennedy 1956). Examples of internal indicators are lignin (Reid and Kennedy 1956), plant pigments (Brisson et al. 1954) and indigestible protein (Forbes 1950). External indicators include barium sulfate (Kane et al. 1956), polyethylene or Cerium-144 (Knapka et al. 1967) and chromium oxide (Cr_2O_3) (Reid and Kennedy 1956). The internal indicator is used for the calculation of dry matter (DM) digestibility as follows:

$$\text{DM digestibility} = 100 - 100\cdot\left[\frac{\%\text{ indicator in feed}}{\%\text{ indicator in feces}}\right]. \quad (2)$$

With digestibility known, dry matter consumption using the external indicator is:

$$\text{DM consumption} = \left[\frac{(\text{total indicator fed})}{(\text{total indicator in feces sample})}\right]\cdot\left[\frac{(\text{DM in feces sample})}{(\%\text{ DM digestibility})}\right]. \quad (3)$$

The feces sample referred to in (3) means that total fecal collection is not necessary. Rather, "grab" samples may be taken at appropriate intervals and the amount of indicator ascertained.

Evidence exists in the literature of wide variability in intake rates derived from the use of lignin as an indicator. Wallace and Van Dyne (1970) found that lignin, especially in immature forage plants may be digested to a large extent by grazing animals.

2.2.2 Fecal Nitrogen Index

The procedure for establishing a fecal nitrogen index is as follows: Conventional feeding trials are carried out with the desired species of herbivore being given forages of varying digestibilities. An equation which relates the concentration of an index substance in the feces (X) and the digestibility or feed-to-feces ratio (Y) is formulated, taking the form:

$$Y = a + bX \quad (4)$$

where b is the slope of the regression and a is the y-intercept. Fecal samples from grazing animals are analyzed and the index substance concentration determined. That concentration is then substituted into the established equation and the digestibility or feed-to-feces ratio predicted.

The fecal nitrogen index requires the measurement of the nitrogen content of the feces. The assumption is that fecal nitrogen is of body origin and that metabolic fecal nitrogen is excreted in proportion to the amount of dry matter consumed and/or digested (Cordova et al. 1978).

Perhaps the primary difficulty in using fecal indices is the initial formulation of the regression equation. In order for it to be accurate, the forage offered the pen--fed animals must be the same in species composition and proportion and in the same phenological stage as the forage plants found on the range. Ideally, once a regression equation has been established, it can be used for all similar animals and pastures. However, fecal nitrogen index regressions are reported to vary according to the season of the year (Minson and Kemp 1961, Streeter 1969, Lambourne and Reardon 1962). Wallace and Van Dyne (1970) have discussed some of the problems found in using results gained from digestion trials to estimate digestibility in freely grazing herbivores. Other sources of error are differences in domestic livestock breeds, age and physiological state of the animals, poor record keeping (Baker 1964) and the fact that the method is used most often with improved pastures, not on rangelands. Streeter (1969) also comments on the lack of standardization in reporting results; some workers report digestible organic matter using fecal nitrogen content and others report feed-to-feces ratios using fecal nitrogen content.

Even with the above mentioned errors, relationships between feed-to-feces ratios (FF) and fecal nitrogen (N) are widely used. Multiple regressions using fecal output (F) and the product of fecal output and nitrogen concentration (FN) as well as feed-to-feces ratios as independent variables have been developed to deal with special circumstances and in order to standardize the formulations used. Arnold and Dudzinski (1963), for example, developed the quadratic expression, $\text{Intake} = 17.2 + 0.2FN + 0.2FN^2 - 3.8N$, for cattle grazing improved pastures in Australia.

Finally, Cordova (1977) concludes that the fecal nitrogen method is better suited to studies of digestibility than for forage intake estimates.

2.2.3 Total Fecal Collection

The total fecal collection method of forage intake estimation requires complete records of the feed or forage consumed and the total collection of feces. Forage consumption is then calculated by combining measurements of fecal output with determinations of digestibility of the forage species (Cordova et al. 1978). Digestibility may be determined by samples collected from esophageal--fistulated animals or, if a suitable regression equation is available, from the fecal nitrogen index (Arnold and Dudzinski 1963).

Kartchner (1975) subjectively estimated that one fecal output measurement required about 70 man hours of field work. Cordova et al. (1978) say this is probably a valid figure if all the details of the measurement (cleaning, weighing and changing fecal bags, adjustment of the collection harnesses, etc.) are considered. Another disadvantage is reported abberant feeding behavior exhibited by harnessed animals and on the harnessed animals' physiology. This effect of the total collection apparatus appears to be largely anecdotal as Cordova et al. (1978) list some seven references where animals were harnessed and bagged for long periods with no apparent adverse effects. Cordova concludes "that total fecal collection may still be the procedure of choice under many situations, in spite of its relatively arduous and time-consuming disadvantages."

Parenthetically, another method of measuring forage intake that bears some resemblance to total fecal collection should be mentioned. It is called "Erizian's Method" and requires initial weighing of an animal prior to being turned out to pasture. Thereafter, attendants follow the animal, collecting feces and urine. The animal is weighed again at the end of the grazing period. Insensible heat loss due to resting, walking and grazing is calculated and added to the final weight of the animal plus the animal waste. The initial weight of the animal is then subtracted from that number, giving the weight of the forage consumed. Schneider et al. (1955) consider this method dependent on the accuracy of the insensible heat loss calculation. They also say the method seems to be the most scientific and perfect, but not of much practical use. The technique is expensive and cannot be considered to subject grazing animals to normal conditions, since they are "constantly followed around day and night by attendants carrying scoops and pails who hurriedly approach the experimental animals at the first sign of defecation or urination."

3.0 ESTIMATES OF FORAGE INTAKE

The values for forage intake presented in this section have undergone some manipulation prior to analysis. Very often researchers design an experiment to answer one specific question, viz. "What is the forage intake rate for sheep?" They measure the intake, perhaps by clipping or mowing, and answer the question posed. For purposes of the present review though, animal weight must also be reported for a paper to provide complete and useful information. Occassionally, researchers report forage intake rate as a percent of total body weight, but the forage weight itself or the weight of the animal(s) used in the study is not reported. Consequently, neither the forage weight nor the animal weight can be calculated. Perhaps the most distressing feature in the body of literature about forage intake rates are the papers that report forage intake weight and animal weight but neglect to report the number of animals used in the study. Then there are the papers that report the requisite information but allow that an animal died during the study, a sampling period was missed, or there was equipment malfunction during the study. These problems lead to a statistical nightmare when one attempts to weight and analyze the reported values for forage intake and make inferences from the statistics derived therefrom. One can only assume that the difficulty and expense involved in measuring forage intake causes many workers to publish the information they have, even though that information is at times incomplete.

The method of reporting forage intake rates is another problem when compiling consumption data. Some rates are reported as organic matter intake (OMI), digestible organic matter intake (DOMI), dry matter intake (DMI), metabolic body weight (MBW), and pounds and kilograms. The literature on forage intake spans a considerable number of years and in that time, units in which forage intake are reported have varied. Examples include amount of DMI or OMI in relation to body weight (Langlands 1968); percent body weight (Van Dyne and Meyer 1964); pounds or kilograms animal^{-1}day^{-1} (Cook et al. 1962, 1972); pounds per 100 pounds of body weight (BW) (Streeter et al. 1968); kilograms per 100 kilograms of BW; grams per kilogram MBW (Scales 1972) and grams per kilogram BW (Bishop et al. 1975). Nevertheless, we have attempted to summarize and interpret forage intake rate data for large grazing herbivores.

The values for forage intake presented in tabular form in this section show animal type, the kind of feed or pasture (in the case of grazing trials) used, the body weight of the animal in pounds and kilograms, the exponent used to calculate metabolic body weight and the metabolic body weight. In instances where an exponent was not reported, it was assumed to be 0.75. The tables further represent the corresponding forage intake rate in pounds animal^{-1}day^{-1}, kilograms animal^{-1}day^{-1}, grams per kilogram of MBW animal^{-1} day^{-1}, and percent body weight animal^{-1}day^{-1}. Any qualifications, stipulations, or designations deemed necessary to the presentation of the data are noted. The season and location of the study and finally the reference from which the data were taken are shown. In cases where information for forage intake or body weight was missing, it was supplied, where possible, by the judicious use of a hand calculator.

To circumvent the problems of omission of data, each forage intake rate entered in a table was considered to have equal weight with all other values in our statistical analyses unless otherwise noted.

In the cases of the domestic sheep and cattle, an extensive literature on forage intake exists. An important consideration for the purposes of our use of this information in optimization models is the normality of the distribution of the values. In several instances below, the forage intake rates are plotted against the normalized scores for those rates. The normal scores and plots were producted by MINITAB II (Ryan et al. 1978). The interpretation is if the resultant plot is a straight line, the values belong to a normal distribution. The MINITAB II routine which accomplishes this manipulation (called NSCORES) is based on work by Filliben (1975), Shapiro and Wilk (1965), and Shapiro and Francia (1972). Essentially, MINITAB ranks the vector of raw data and compares it to the distribution of a standard normal; a distribution with a mean of zero and standard deviation of one. As an example, a distribution of 100 data points would have, if normal, 68% of the data points within one standard deviation of the mean and 95% of the data points within two standard deviations of the mean. The ordered vector of raw data is compared to the expected distribution using percentages of the standard normal and the normal scores are assigned accordingly. The correlation coefficient is then used to ascertain significance. Bear in mind that the correlation is not between the original data and the normal scores but between the ordered vector of original data and a truely normal distribution of points which, when normalized would fall on a straight line that would pass through the origin and the mean of the normal scores. We used this tool extensively in the analysis of cattle and sheep intake data.

3.1 Domestic Herbivores

This subsection considers domestic livestock, cattle and sheep. Except where specified, forage intake rates are derived from grazing trails.

3.1.1 Cattle

Some 58 forage intake rates for cattle (Bos sp.) are presented in Table C2. As mentioned above however, some information is not reported in several of the cited papers. For example, Baker (1976) reports forage intake as percent body weight while Connor et al. (1963) and Greenhalgh and Reid (1969) report forage intake rates but do not specify animal body weight. Streeter et al. (1968) report forage intake rates per 100 pounds body weight. The various ways of expressing forage intake mean that the following sections use different numbers for the statistical analysis of the intake rates.

3.1.1.1 Metabolic Body Weight (MBW). The values given for metabolic body weight (MBW) in Table C2 were calculated by taking the three-quarter power of the body weight where no metabolic body weight was calculated in the reference. In some instances (Corbett et al. 1963, Holms et al. 1961), metabolic body weight was figured using body weight to the 0.73 power. The 33 values tabulated for metabolic body weight have a mean of 78.0 kg and standard deviation of 14.06. The minimum value of 48.5 kg was reported by Holms et al. (1961) for calves in England in late summer. The maximum value of 108.5 kg came from Holms and Osman (1960) for a dairy cow experiment in England.

3.1.1.2 Kilograms Animal^{-1}Day^{-1}. Table C2 lists 44 entries for cattle for forage intake as kilograms per animal per day. The mean (reported over a range in some studies) of the reported value is 7.0 to 7.9 kg animal^{-1}day^{-1} with a midpoint of 7.5 kg animal^{-1}day^{-1}. The standard deviation is 2.64 to

Table C2. Reported forage intake rates for domestic cattle derived from grazing trials.

ANIMAL	PASTURE TYPE	BODY WEIGHT lbs	BODY WEIGHT kg	MBW[a] (kg)	MBW[a] exponent	FORAGE INTAKE (animal^{-1}day^{-1}) lbs	kg	g/kgMBW	% BW
Cattle	Cocksfoot	799.7	363.5[b]	83.2	0.75	14.8	6.72	80.8	1.85
Cattle	Pasture-legumes	799.7	363.5[b]	83.2	0.75	16.8	7.63	91.7	2.1
Cattle	Cocksfoot	799.7	363.5[b]	83.2	0.75	16.1	7.31	87.9	2.01
Cows	Avena sp. seeded pasture	945.9	429.0	94.3	0.75	17.2	7.8	82.7	1.8
Steers	Pasture								3.0
Cattle	Pasture								1.7
Heifers	Pasture								2.6
Heifers	Shortgrass prairie	591.9	268.5	66.3	0.75	16.3	7.4	111.8	2.76
Heifers	Shortgrass prairie	536.8	243.5	61.6	0.75	14.2	6.43	104.4	2.64
Heifers	Shortgrass prairie	583.7	264.7	65.6	0.75	15.4	6.96	106.1	2.63
Heifers	Shortgrass prairie	554.9	251.7	63.2	0.75	13.8	6.29	99.5	2.5
Steers	Sagebrush-grass range					8.4-10.4	3.8-4.7	69.4-85.9	
Steers	Desert shrub range					5.1-9.0	2.3-4.1	42.1-74.4	
Dairy Cows	Pasture	982.5	445.6	85.8	0.73	23.7	10.7	124.7	2.4
Cattle	Shortgrass prairie	643.9	292.0	70.6	0.75	15.3	7.0	98.8	2.39
Cattle	Shortgrass prairie	604.2	274.0	67.3	0.75	14.4	6.6	97.3	2.39
Dairy Cows	Ryegrass, cocksfoot					20.7	9.4		
Cow	Ryegrass-clover	1300.0	589.6	105.3	0.73	23.5	10.7	101.2	1.8
Heifer	Ryegrass-clover	790.0	358.3	73.2	0.73	20.8	9.5	128.4	2.6
Calf	Ryegrass-clover	450.0	204.1	48.5	0.73	14.3	6.5	134.0	3.2
Dairy Cows	Ryegrass-clover	1141.0	517.5	108.5	0.75	30.4	13.8	127.1	2.7
Steer	Agropyron pasture	606.4	275.0	67.5	0.75	14.0	6.4	94.8	2.3
Steer	Agropyron pasture	594.4	270.0	66.6	0.75	16.2	7.3	110.0	2.7
Cattle	Wiregrass-pine range	879.3	399.0	89.3	0.75	20.1	9.1	101.9	2.3
Cattle	Wiregrass-pine range	862.0	392.0	88.1	0.75	20.0	9.1	103.2	2.3
Cattle	Wiregrass-pine range	849.2	386.0	87.1	0.75	18.0	8.18	93.9	2.12
Cattle	Wiregrass-pine range	820.6	373.0	84.9	0.75	12.0	5.44	64.1	1.46
Cattle	Shortgrass prairie	604.0	273.9	67.3	0.75	21.7	9.9	147.0	3.6
Cattle	Shortgrass prairie					16.5-33.5	7.5-15.2	135.6-204.2	
Steers	Shortgrass prairie	589.6	268.0	66.2	0.75	11.8	5.36	81.0	2.0
Steers	Shortgrass prairie	589.6	268.0	66.2	0.75	10.0	4.55	68.7	1.7
Steers	Shortgrass prairie	589.6	268.0	66.2	0.75	15.3	6.97	105.3	2.6
Cows	Bermudagrass							109.5	
Calves	Bermudagrass							42.3	
Steers	Shortgrass prairie	1040.6	473.0	101.4	0.75	23.8	10.8	106.5	2.3
Dairy Cows	Seeded pasture	903.4	409.8	91.1	0.75	28.2	12.8	140.5	3.1
Cows	Rangeland					18.0-39.4	8.2-17.9	76.0-145.0	
Cattle	Irrigated pasture					17.5	7.97	116.1	
Cattle	Improved pasture					4.3-12.8	1.95-5.8	31.2-83.2	
Cattle	Improved pasture					5.3-15.0	2.4-6.8	42.7-101.7	
Cattle	Tallgrass prairie								0.96
Cattle	Fescue--orchardgrass pasture								1.3
Cattle	Shortgrass prairie	1012.0	460.0	99.3	0.75	11.3	5.15	51.9	1.12
Heifer	Sandhill range	726.0	330.0	77.4	0.75	7.26	3.3	42.6	1.0
Steers	Sandhill range					6.4-13.4	2.9-6.1	41.3-86.6	
Steers	Sandhill range							36.7-75.7	
Steers	Sandhill, blue grama range							23.1-46.2	
Dairy Cows	Digitaria pasture				0.75			36.7	
Dairy Cows	Chloris pasture				0.75			64.1	
Dairy Cows	Setaria pasture				0.75			58.5	
Steers	Desert shrub range					11.7-22.4	5.3-10.2	46.7-89.8	
Steers	Sandhill range					1.8-2.5/CWT[c]	0.8-1.1/45kg	48.0-64.9	
Steers	Sandhill range					1.4-1.7/CWT	0.64-0.77/45kg	37.6-44.1	
Cows	Native meadow forage					20.9-26.0	9.5-11.8	97.0-121.0	
Cattle	Annual grass-shrub	701.2	318.0	75.3	0.75	10.5	4.77	63.3	1.5
Cattle	Annual grass-shrub	712.2	323.0	76.2	0.75	12.5	5.65	74.2	1.75
Cattle	Annual grass-shrub	710.0	322.0	76.0	0.75	13.1	5.96	78.4	1.85
Steer	Bermudagrass pasture	626.0	283.9	69.2	0.75	14.1	6.4	92.5	2.3

[a] metabolic body weight [b] mid-point of reported range [c] per hundred pounds body weight

REPORTED as	REMARKS	SEASON	LOCATION	REFERENCE
ØMI		Late spring	England	Alder & Minson 1963
ØMI		Summer	England	
ØMI		Summer	England	
ØMI	Strip grazing		Australia	Chacon et al. 1976
ØM	Animal weight not specified	April-June	England	Baker 1976
ØM	Animal weight not specified	April-June	England	
ØM	Animal weight not specified	April-June	England	
DM	Light grazing	June-September	NE Colorado	Dyck & Bement 1971
DM	Heavy grazing	June-September	NE Colorado	
DM	Light grazing	June-September	NE Colorado	Dyck & Bement 1972
DM	Heavy grazing	June-September	NE Colorado	
DMI		Summer	N. Nevada	Connor et al. 1963
DMI		Summer	S. Nevada	
ØMI		Spring-summer	Scotland	Corbett et al. 1963
	Light grazing	Yearlong	NE Colorado	Dean & Rice 1975
	Heavy grazing	Yearlong	NE Colorado	
DØMI	Animal weight not specified	Spring-summer	Scotland	Greenhalgh & Reid 1969
ØMI		Late summer	England	Holms et al. 1961
ØMI		Late summer	England	
ØMI		Late summer	England	
DMI		Late summer	England	Holms & Osman 1960
DMI		Spring	SE Oregon	Handl & Rittenhouse 1972
DMI		Spring	SE Oregon	Handl & Rittenhouse 1975
		Spring	Georgia, USA	Hale et al. 1962
		Summer	Georgia, USA	
		Fall	Georgia, USA	
		Winter	Georgia, USA	
DMI -		Spring-summer	E. Colorado	Hyder et al. 1966
DMI		Summer	E. Colorado	Hyder et al. 1968
DM	In vitro method	June-August	Wyoming	Jeffries & Rice 1969
DM	Lignin method	June-August	Wyoming	
DM	Pepsin-HCl digestion method	June August	Wyoming	
DM	Animal weight not specified, N-fertilized pasture	May-July	Oklahoma	Horn et al. 1979
DM	As above	May-July	Oklahoma	
DM	Light grazing	Summer	Texas	McClung et al. 1976
DMI			Georgia, USA	McCullough 1956
DMI	Lactating animals	Summer	Oregon	Kartchner 1975
DMI				Lake et al. 1974
DØMI	Brahman cattle		Australia	Moran 1976
DØMI	Hereford cattle		Australia	
ØM	Animal weight not specified	June-October	Kansas	Rao et al. 1974
DM	Animal weight not specified	Growning season	Nevada	Ridley et al. 1963
		Summer	NE Colorado	Rice et al. 1974
		Winter	Nebraska	Rittenhouse et al. 1970
DMI		May-November	Colorado	Scales 1972
DMI			Colorado	
DMI			Colorado	
DMI		October-March(summer)	Australia	Stobbs & Sandland 1972
DMI		October-March(summer)	Australia	
DMI		October-March(summer)	Australia	
DMI			Nevada	Smith et al. 1963
DMI	Study done in 1964		Nebraska	Streeter et al. 1968
DMI	Study done in 1965		Nebraska	
DMI			Colorado	Streeter et al. 1974
		Early summer	N. California	Van Dyne & Meyer 1964
		Midsummer	N. California	
		Late summer	N. California	
DMI		Summer	Oklahoma	Wilson et al. 1977

3.00 while the minimum and maximum reported values are 1.95 and 17.9 kg animal^{-1}day^{-1} respectively. Kartchner (1975) reports the highest intake rate. He dealt with lactating animals. Moran (1976) reports a range of rates, the low end of the range (1.95 kg animal^{-1}day^{-1}) being the lowest reported value in Table C2. A plot of forage intake rate in kilograms animal^{-1}day^{-1} versus the normalized scores of intake rate in kilograms of forage animal^{-1}day^{-1} is shown in Figure C2. (Where a range of consumption values was reported in a study, as in the case of Moran (1976), the mid-point of the range was used in the normalized scores plot. This convention is followed in all subsequent plots.)

3.1.1.3 Grams per kilogram MBW Animal^{-1}Day^{-1}. There are 52 entries in Table C2 which report forage intake as grams per kilogram MBW animal^{-1}day^{-1}. (It should be remembered that not every reference with such an entry supplied this information. The values for this rate, in many instances, were calculated from data in the article.) The mean rate of intake ranged from 84.6 to 94.2 grams kg^{-1} MBW with a midpoint in the range of 89.4. The standard error was a range of 31.6 to 30.3 respectively. This indicates that the upper range of values, when used to calculate standard error, gave less dispersion about the mean and were more closely in accord with papers reporting one value. The minimum for this rate was reported as 31.2 g kg^{-1} MBW (for a calf) and the maximum was 204.2 g kg^{-1} MBW. A plot of forage intake in grams per kilogram of MBW animal^{-1}day^{-1} versus the normalized scores for this distribution is shown in Figure C3. The plotted points fall nearly on a straight line, indicating more normality in this distribution than in the previous normalized plot. It is reasonable to expect such a result since the forage intake is in this instance a ratio of intake to body weight.

3.1.1.4 Percent Body Weight. For the 38 entries in Table C2 which report forage intake as a percentage of body weight, the mean was 2.21 pecent with a standard deviation of 0.59. The maximum and minimum were 3.6 and 0.96 respectively.

A plot of forage intake in percent body weight versus the normalized scores of forage intake is shown in Figure C4. Since it again shows forage intake as a ratio of body weight, the points on the plot line up, indicating a high degree of normality.

A summary of the information in Table C2 is presented in Table C3.

A plot of forage intake in percent body weight versus body weight (in kilograms) is shown in Figure C5. This plot emphasizes the variances in forage intake rates. The correlation coefficient between percentage body weight and body weight is 0.078; virtually no correlation. Yet, Figure 5 does show a clustering along a line with a slope of zero at the mean forage intake rate of 2.2%.

3.1.2 Sheep

Some 55 reports of forage intake rates for domestic sheep (*Ovis aries*) are shown in Table C4. Again, not every reference reported supplied

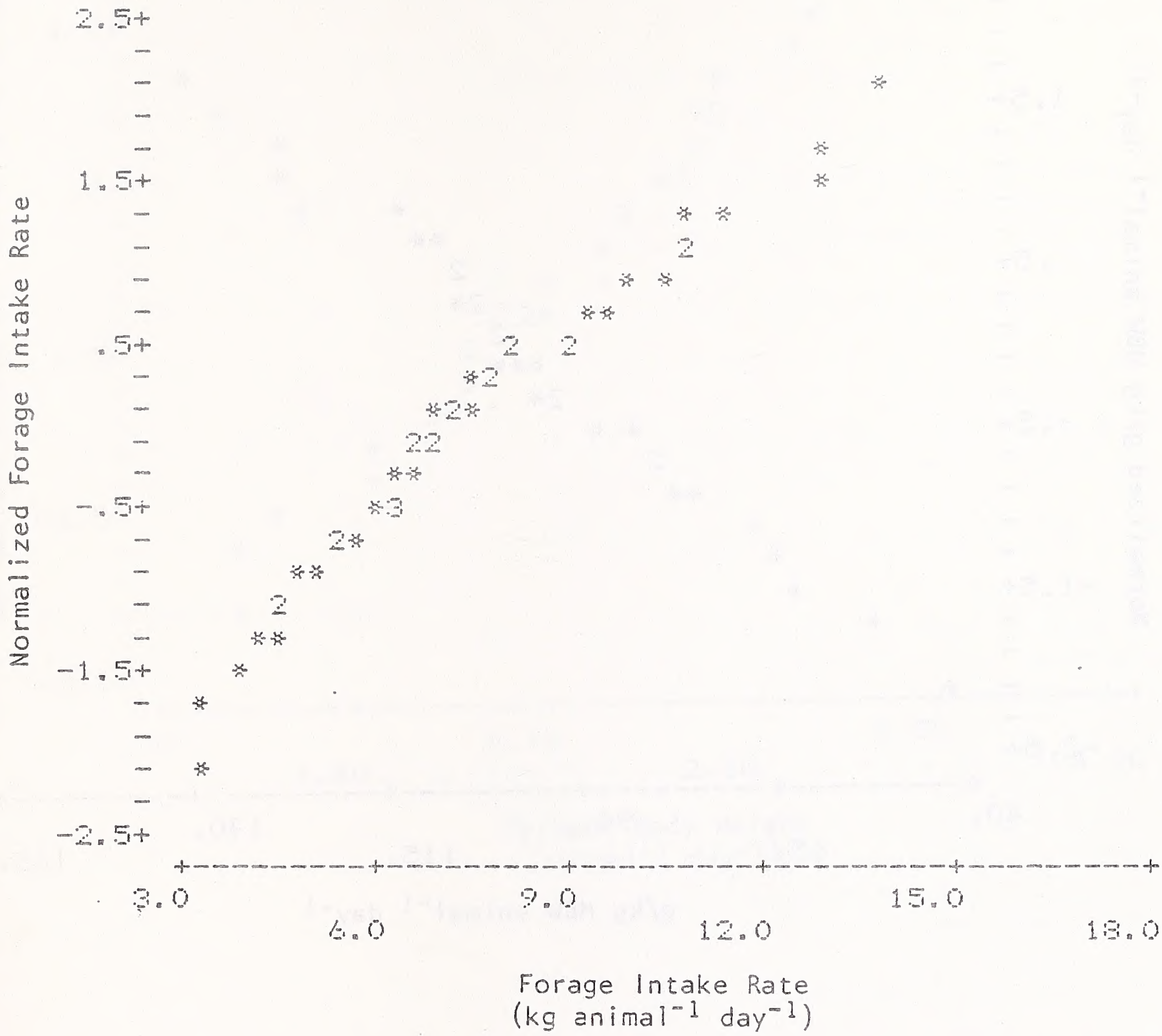

Figure C2. Forage intake rates for cattle expressed as kilograms animal^{-1} day^{-1} versus the normalized scores of kilograms animal^{-1} day^{-1}.

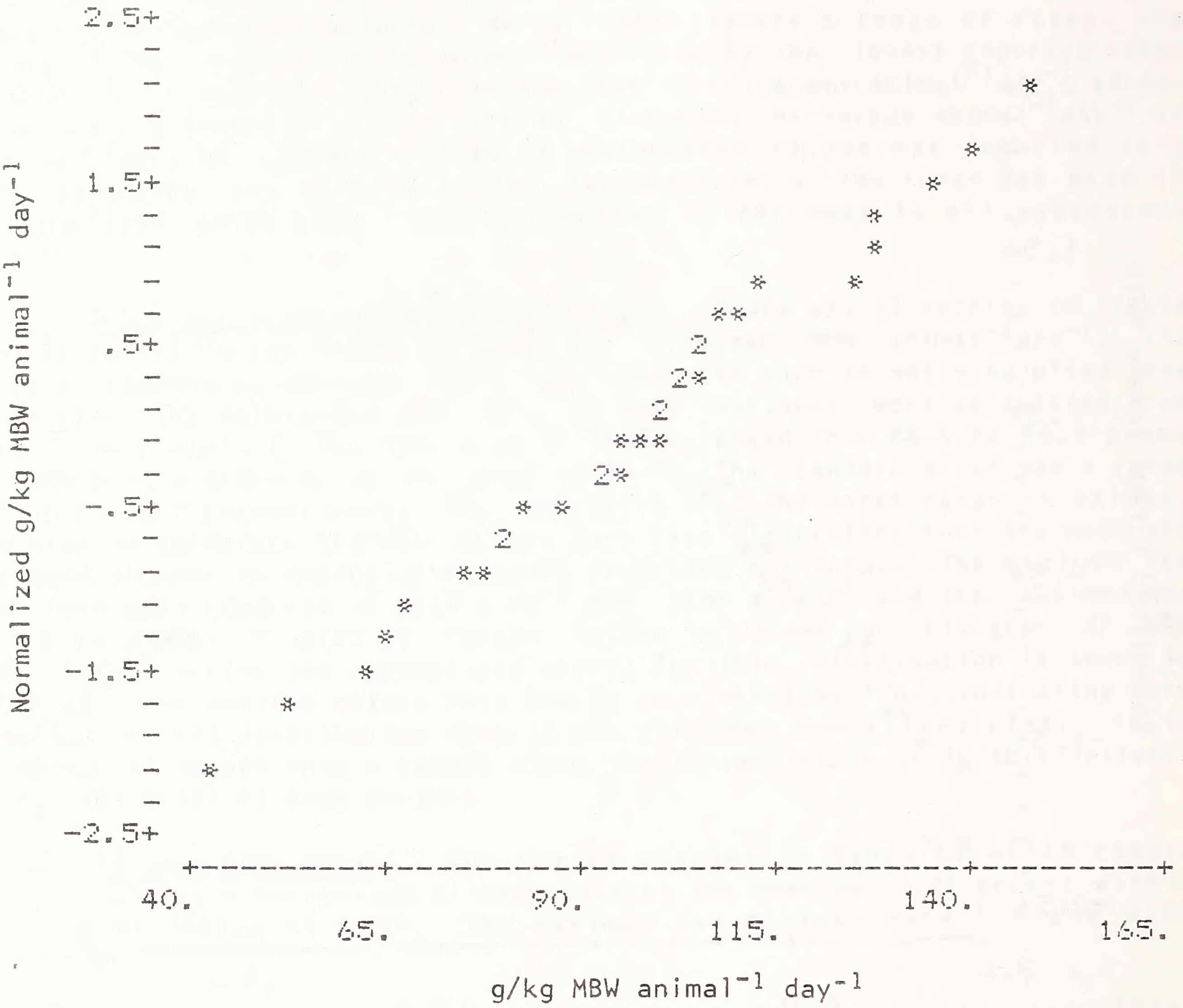

Figure C3. Forage intake rates for cattle expressed as grams per kilogram of metabolic weight animal^{-1} day^{-1} versus the normalized scores of grams per kilogram of metabolic body weight animal^{-1} day^{-1}.

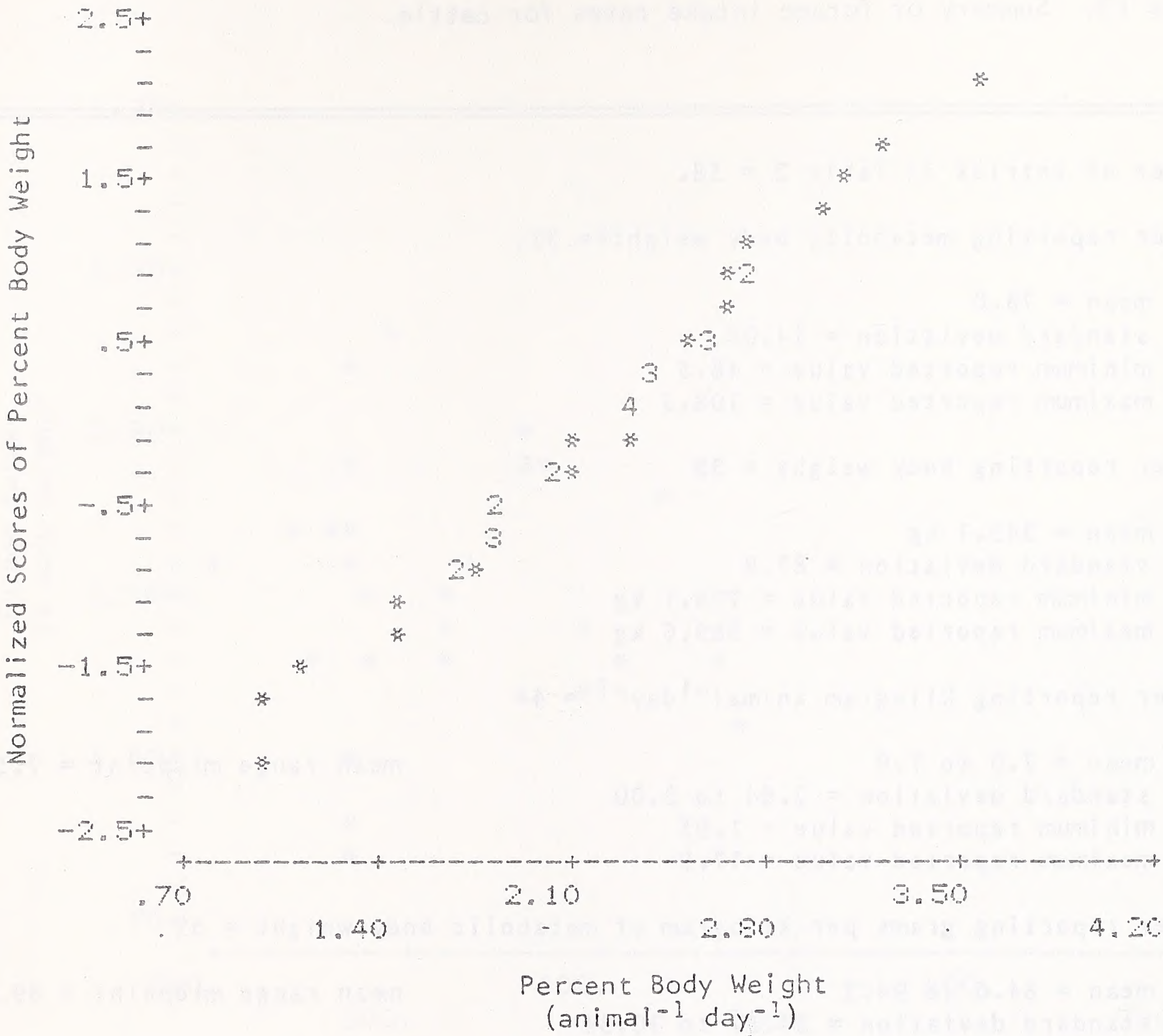

Figure C4. Forage intake rates for cattle expressed as percent body weight animal^{-1} day^{-1} versus the normalized scores of percent body weight animal^{-1} day^{-1}.

Table C3. Summary of forage intake rates for cattle.

Number of entries in Table 2 = 58.

Number reporting metabolic body weight = 33.

mean = 78.0
standard deviation = 14.06
minimum reported value = 48.5
maximum reported value = 108.5

Number reporting body weight = 33

mean = 343.1 kg
standard deviation = 87.9
minimum reported value = 204.1 kg
maximum reported value = 589.6 kg

Number reporting kilogram animal^{-1}day^{-1} = 44

mean = 7.0 to 7.9 mean range midpoint = 7.5
standard deviation = 2.64 to 3.00
minimum reported value = 1.95
maximum reported value = 17.9

Number reporting grams per kilogram of metabolic body weight = 52

mean = 84.6 to 94.2 mean range midpoint = 89.4
standard deviation = 31.57 to 30.34
minimum reported value = 31.2
maximum reported value = 204.2

Number reporting % body weight = 38

mean = 2.21
standard deviation = 0.59
minimum reported value = 0.96
maximum reported value = 3.6

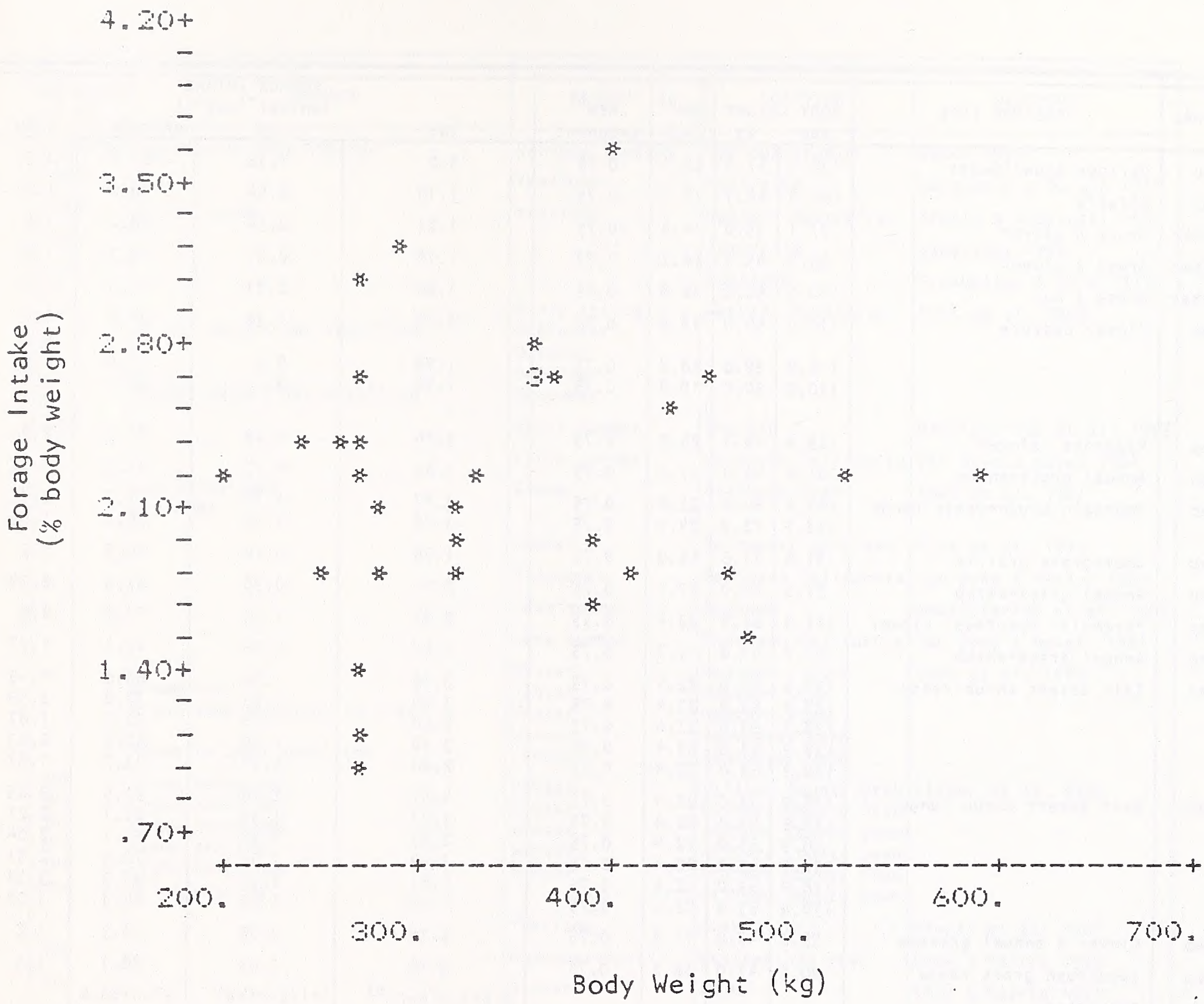

Figure C5. Forage intake rates for cattle in percent of body wieght as a function of body weight in kilograms.

Table C4. Reported forage intake rates for domestic sheep derived from grazing trials.

ANIMAL	PASTURE TYPE	BODY WEIGHT lbs	BODY WEIGHT kg	MBW[a)] (kg)	MBW[a)] exponent	FORAGE INTAKE (animal^{-1}day^{-1}) lbs	kg	g/kgMBW	% BW
Sheep	Various experiments	136.5	61.9	22.1	0.75	3.0	1.36	61.5	2.2
Sheep	Alfalfa	100.8	45.7	17.6	0.75	1.19	0.54	30.7	1.2
Whether	Grass & clover	77.1	35.0	14.4	0.75	1.21	0.55	38.2	1.6
Whether	Grass & clover	99.3	45.3	16.2	0.73	1.78	0.81	49.9	1.3
Whether	Grass & hay	110.0	50.0	18.8	0.75	1.90	0.87	46.3	1.7
Sheep	Clover pasture	110.0	50.0	18.8	0.75	2.97	1.35	71.6	2.7
									2.0
		110.0	50.0	18.8	0.75	1.98	0.9	47.8	1.8
		110.0	50.0	18.8	0.75	1.54	0.7	37.1	1.4
									1.9
Sheep	Ryegrass clover	129.4	58.7	20.9	0.75	3.74	1.69	81.2	2.9
Sheep	Annual grass-shrub	101.4	46.0	17.7	0.75	1.69	0.77	43.3	1.67
Sheep	Mountain brush-grass range	141.3	64.0	22.6	0.75	3.87	1.76	77.7	2.75
		158.7	72.0	24.7	0.75	3.08	1.40	56.5	1.95
Sheep	Shortgrass prairie	81.6	37.0	15.0	0.75	1.55	0.70	46.9	1.9
Sheep	Annual grass-shrub	97.0	44.0	17.1	0.75	2.16	0.98	57.3	2.24
Sheep	Perennial ryegrass clover	147.3	66.8	23.4	0.75	3.81	1.73	73.8	2.6
Sheep	Annual grass-shrub	94.8	43.0	16.8	0.75	1.67	0.76	45.1	1.77
Sheep	Salt desert shrub range	138.9	63.0	22.4	0.75	3.39	1.54	68.6	2.45
		138.9	63.0	22.4	0.75	3.59	1.63	72.8	2.59
		138.9	63.0	22.4	0.75	2.60	1.18	52.7	1.87
		138.9	63.0	22.4	0.75	3.10	1.40	62.5	2.23
		138.9	63.0	22.4	0.75	2.60	1.18	52.7	1.87
Sheep	Salt desert shrub range	138.9	63.0	22.4	0.75	4.51	2.05	91.5	3.25
		138.9	63.0	22.4	0.75	3.07	1.39	62.1	2.21
		138.9	63.0	22.4	0.75	2.83	1.28	57.1	2.04
		138.9	63.0	22.4	0.75	3.49	1.58	70.5	2.51
		138.9	63.0	22.4	0.75	4.61	2.09	93.3	3.32
		138.9	63.0	22.4	0.75	4.19	1.09	84.8	3.02
Sheep	Clover & annual grasses	99.2	45.0	17.4	0.75	2.18	0.99	56.9	2.2
Sheep	Sagebrush grass range	90.4	41.0	16.2	0.75	3.16	1.43	88.3	3.5
Sheep	Rangeland					2.2-3.4(cwt)[b)]	1-1.5(45kg)	57.0-38.0	
Sheep	Rangeland	130.1	59.0	21.3	0.75	3.25	1.47	69.0	2.5
		130.1	59.0	21.3	0.75	3.25	1.47	69.0	2.5
		130.1	59.0	21.3	0.75	2.86	1.30	61.0	2.2
		130.1	59.0	21.3	0.75	3.51	1.59	74.6	2.7
		130.1	59.0	21.3	0.75	3.90	1.77	83.1	3.0
		130.1	59.0	21.3	0.75	2.99	1.36	63.7	2.3
		130.1	59.0	21.3	0.75	3.12	1.42	66.4	2.4
		130.1	59.0	21.3	0.75	3.64	1.65	77.5	2.3
Sheep	Mature Lolium pasture					1.71(cwt)	0.78(45kg)	44.1	
Sheep	Perennial ryegrass					1.1-4.7	0.5-2.12	24.3-94.5	
Sheep	Pasture	72.8	33.0	13.8	0.75	1.4-2.0	0.65-0.92	49.8-70.5	2.0-2.8
Sheep	Ryegrass & clover	128.6	58.3	21.1	0.75	2.7	1.24	58.9	2.13
		147.3	66.8	23.4	0.75	2.5	1.13	48.4	1.69
		139.8	63.4	22.5	0.75	1.7	0.76	33.8	1.20
		147.1	66.7	23.3	0.75	1.8	0.82	35.4	1.23
Sheep	Seeded pasture	73.8	33.5	13.9	0.75	0.95	0.43	30.9	1.29
Sheep	Native pasture					2.1-2.8	0.95-1.25	63.3-78.6	
Sheep	Phalaris & Trifolium pasture					1.3-2.2	0.6-0.98	4.3-56.1	
Sheep	Native grassland					2.0-2.4	0.93-1.1	53.2-62.9	
Sheep	Improved grassland					1.6-2.3	0.74-1.04	42.3-59.5	
Sheep	Desert range					2.5-3.2	1.1-1.5	65.7-83.3	
Sheep	Irrigated alfalfa					1.0(cwt)	0.45(45kg)	26.0	
Sheep	Perennial & annual pastures					1.37-3.13	0.62-1.42	39.7-78.3	

a) metabolic body weight

b) per hundred pounds body weight

Table C4. (Continued)

REPORTED as	REMARKS	SEASON	LOCATION	REFERENCE
various	Reports on many papers	Various studies	various studies	Baker 1964
DØMI		Yearlong	Australia	Langlands & Donald 1977
DØMI	3 year study	Yearlong	Western Australia	Arnold & Dudzinski 1967
DØMI			Australia	Langlands 1968
DMI			Scotland	Greenhalgh & Reid 1971
		Early spring	Western Australia	Fels et al. 1959
	Animal weight not specified	September		
		October		
		December		
	Animal weight not specified	December		
ØMI		Early summer	England	Hadjipieries et al. 1965
		Early summer	Northern California	Van Dyne & Meyer 1964
	Lactating ewes	Summer	Northern Utah	Cook et al. 1961
	Dry ewes			
		Summer	Northeast Colorado	Rice et al. 1974
		Midsummer	Northern California	Van Dyne & Meyer 1964
		Late summer	England	Hadjipieries et al. 1965
		Late summer	Northern California	Van Dyne & Meyer 1964
		Winter	Western Utah	Cook et al. 1953
	Mixed diet	Winter	Western Utah	
	Black sage dominant in diet	Winter	Western Utah	
		Winter	Southwest Utah	
	Range in poor condition	Winter	Southwest Utah	
DMI	Heavy range use	Winter	Millard County Utah	Pieper et al. 1959
DMI	Light range use	Winter	Millard County Utah	
DMI	Heavy range use	Winter	Millard County Utah	
DMI	Heavy grazing	Winter	Millard County Utah	
DMI	Light range use	Winter	Millard County Utah	
DMI	Light grazing		Millard County Utah	
		Yearlong	Australia	Arnold et al. 1964
DMI		November-April	Westcentral Utah	Cook & Harris 1950
DMI		Winter	Utah	Cook & Harris 1951
DMI	Smother weed dominant	Spring-summer	Utah	Cook et al. 1956
DMI	Russian thistle dominant			
DMI	Western wheatgrass dominant			
DMI	Tall wheatgrass dominant			
DMI	Intermediate wheatgrass dominant			
DMI	Beardless wheatgrass dominant			
DMI	Pubescent wheatgrass dominant			
DMI	Crested wheatgrass dominant			
DMI			Australia	Vercoe & Pearce 1961
DØMI			England	Young & Newton 1974
ØMI			Australia	Donnely et al. 1974
DØMI		Winter	Australia	Pearce et al. 1962
DØMI		Spring	Australia	
DØMI		Summer	Australia	
DØMI		Fall	Australia	
ØMI			Australia	Langlands 1969
ØMI			Australia	Langlands & Bowles 1974
DØMI			Australia	Arnold 1975
DØMI			California	Wilson 1971
DØMI			California	
	Poor to good range condition		Utah	Cook et al. 1962
			New Mexico	Orcasberro 1974
	Range reflects extremes of stocking rates		Australia	Arnold et al. 1964

information for all columns in the table. Where possible we calculated the appropriate values from the data presented by the original authors. Note is made of the papers by Fels et al. (1959) and Cook et al. (1953, 1956). Each study reports a single body weight of the animals used in the experiments even though several variables were tested. Because the body weights are reported this way, a number of normal scores tests were not performed on the sheep data.

3.1.2.1 Metabolic Body Weight. The average of the metabolic body weights is 20.3 kg (n = 43) and the standard deviation is 2.90. The minimum tabulated body weight is 13.8 (derived from a paper by Donnely et al. 1974) while the maximum tabulated MBW was 24.7 kg from the work of Cook et al. (1961). The average body weight tabulated was 55.6 kg with a standard deviation of 10.16 and a minimum and maximum of 33 kg and 72 kg respectively.

3.1.2.2 Kilograms Animal^{-1}Day^{-1}. Some 50 values for forage intake, expressed as kilograms animal^{-1}day^{-1} are tabulated in Table 4. They range from a minimum a minimum of 0.43 kg reported by Langlands (1969) to a maximum of 2.12 kg reported by Young and Newton (1974). Since several authors reported ranges of forage intake, the means and standard errors ranged from 1.16 $\pm$ 0.42 to 1.25 $\pm$ 0.41.

A plot of forage intake for sheep expressed as kilograms animal^{-1}day^{-1} versus the normalized scores for kilograms animal^{-1}day^{-1} is shown in Figure C6. The figure does not show linearity indicating the data are not normally distributed.

3.1.2.3 Grams per Kilogram MBW Animal^{-1}Day^{-1}. Table C4 shows 53 entries for forage intake for sheep expressed as grams per kilogram MBW animal^{-1}day^{-1}. Again, a range of values was reported by several authors giving a range of the mean and standard deviation of 57.6 $\pm$ 17.29 to 62.0 $\pm$ 17.76. The minimum and maximum tabulated values are 24.3 and 94.5 respectively. Using the midpoint of the mean range, where necessary, a plot of forage intake for sheep in grams per kilogram MBW animal^{-1}day^{-1} versus the normalized scores for this way of reporting intake rates is shown in Figure C7. As may be seen, the curve follows a near straight line, giving an indication that reporting forage intake as a ratio of intake to body size produces estimates that are members of a normal distribution.

3.1.2.4 Percent Body Weight. Forage intake in Table C4 for sheep expressed as percent of body weight yields a mean of 2.20 to 2.22 with standard deviations of 0.57 to 0.58, and maximum and minimum values of 3.32 and 1.20 respectively. A plot of percent body weight versus the normalized scores for percent body weight is shown in Figure C8. As this expression of forage intake is a ratio of intake to body size, the curve in Figure C8 is straight, indicating a normal distribution.

A summary of forage intakes for sheep is shown in Table C5.

3.1.2.5 Pen--Feeding Studies. A representative sample of 4 feeding trials for sheep was selected from the literature to compare with the forage intake rates shown for sheep in Table C4. The values reported in those studies are tabulated in Table C6. The average body weight in kilograms is 55.1 which is is within the standard deviation of the mean body weight for the grazing

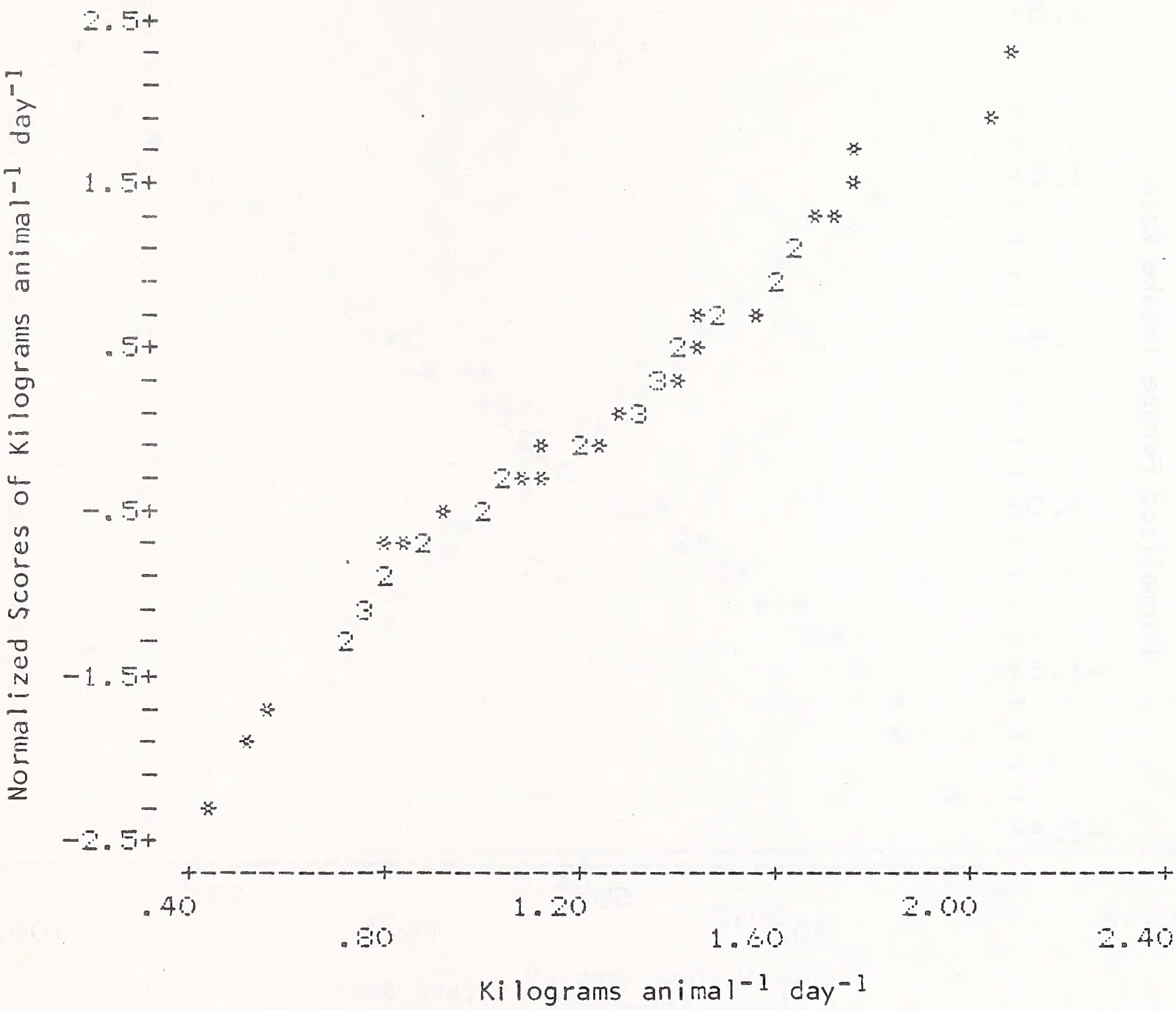

Figure C6. Forage intake rates for sheep expressed as kilograms animal^{-1} day^{-1} versus the normalized scores of kilograms animal^{-1} day^{-1}.

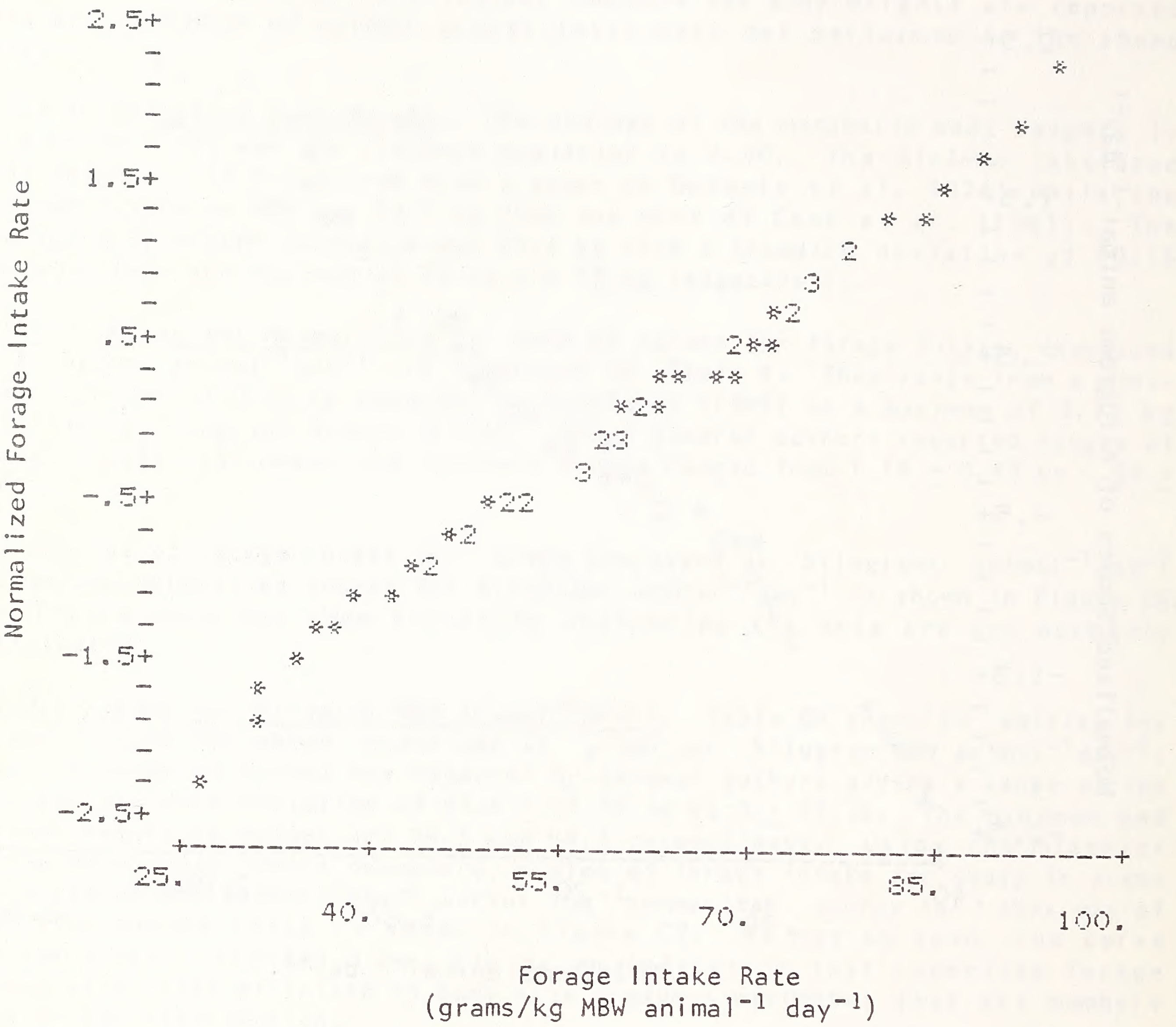

Figure C7. Forage intake rates for sheep as grams per kilogram of metabolic body weight animal^{-1} day^{-1} versus the normalized scores of grams per kilogram of metabolic body weight animal^{-1} day^{-1}.

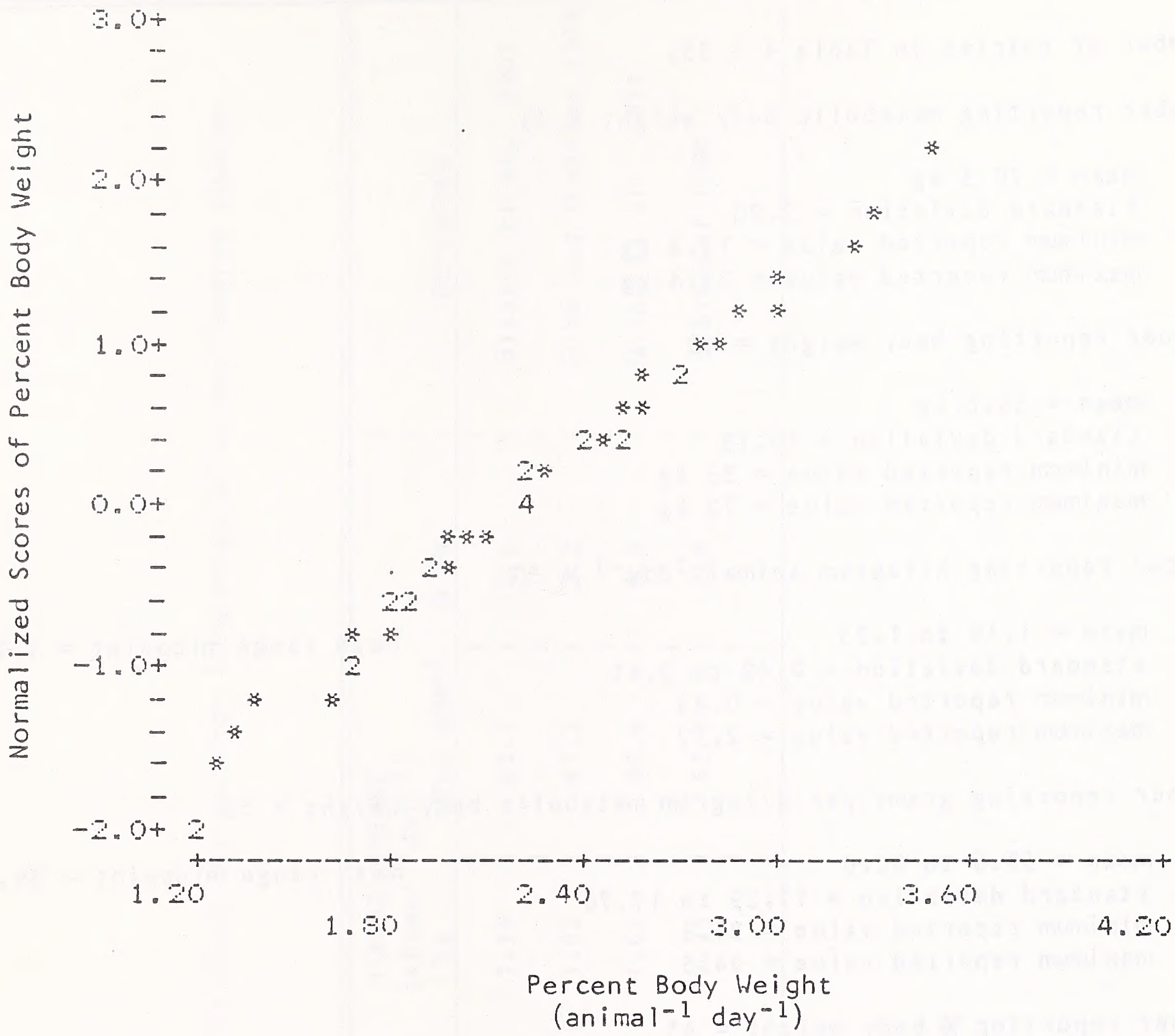

Figure C8. Forage intake rates for sheep expressed as percent body weight animal^{-1} day^{-1} versus the normalized scores of percent body weight animal^{-1} day^{-1}.

Table C5. Summary of forage intake rates for sheep.

Number of entries in Table 4 = 55.

Number reporting metabolic body weight = 43

- mean = 20.3 kg
- standard deviation = 2.90
- minimum reported value = 13.8 kg
- maximum reported value = 23.4 kg

Number reporting body weight = 43

- mean = 55.6 kg
- standard deviation = 10.16
- minimum reported value = 33 kg
- maximum reported value = 72 kg

Number reporting kilogram $animal^{-1} day^{-1}$ = 50

- mean = 1.16 to 1.25 — mean range midpoint = 1.21
- standard deviation = 0.42 to 0.41
- minimum reported value = 0.43
- maximum reported value = 2.12

Number reporting grams per kilogram metabolic body weight = 53

- mean = 57.6 to 62.0 — mean range midpoint = 59.77
- standard deviation = 17.29 to 17.76
- minimum reported value = 24.3
- maximum reported value = 94.5

Number reporting % body weight = 45

- mean = 2.20 to 2.22 — mean range midpoint = 2.21
- standard deviation = 0.57 to 0.58
- minimum reported value = 1.20
- maximum reported value = 3.32

Table C6. Forage intake rates for sheep derived from 4 representative pen-feeding studies.

BODY WEIGHT lbs	BODY WEIGHT kg	FORAGE INTAKE ($animal^{-1} day^{-1}$) lbs	kg	g/kg MBW[a]	% BW	REFERENCE
121.3	55.0	2.62	1.19	62.7	2.2	Blaxter et al. 1961
179.9	81.6	4.01	1.82	67.2	2.2	Gibb and Treacher 1978
113.3	51.4	3.68	1.67	86.9	3.3	Milne et al. 1978
71.7	32.5	1.74	0.79	62.0	2.4	Schinckel 1960

a) metabolic body weight

trials. The average forage intake rate shown in Table C6 is 1.4 $\pm$ 0.47 kg animal^{-1}day^{-1}, 69.7 $\pm$ 11.7 grams per kilogram MBW animal^{-1}day^{-1}, and 2.5 $\pm$ 0.52 percent body weight animal^{-1}day^{-1}.

The values for forage intake rates from feeding trials are higher than the rates of intake derived from grazing studies. The conclusion is that use of feeding trial forage intake values in the optimization models discussed in Section 1.0 would overestimate the forage required for sheep. For that reason, grazing trial derived rates of forage intake are used for cattle and sheep.

It is not possible to use grazing trial forage intake rates for wildlife and horses, since grazing trial information is not extant in the literature. The lone exception is the case of bison which is considered next.

3.2 Bison

Forage intake rate studies for bison (*Bison bison*) are rare. The work by Rice et al. (1974), done under the auspices of the International Biological Program (IBP) Grassland Biome study, reports a value for forage intake in bison. This value is for summer only. Interestingly, the work was a grazing study as opposed to a feeding trial with caged animals, but unfortunately it appears to be the only intake rate study of bison to reach print. Information from Rice et al. (1974) is presented in Table C7.

3.3 Bighorn Sheep

Two values for forage intake of bighorn sheep (*Ovis canadensis*) are reported in Table C8. The first of 1.3 kilograms animal^{-1}day^{-1} for an animal weighing 68 kilograms comes from a feeding trial study by Chappel and Hudson (1978). They used concentrate feed pellets in their study.

The second value for forage intake in bighorn sheep is neither a grazing or a feeding trial. It comes instead from values given in a memorandum from the State Director of the Bureau of Land Management (BLM) to the Director of the Denver Service Center (D-360), dated 3 October 1978. The information given in this memo, titled "Methodology and References Used to Determine Forage Consumption Rates for Big Game in the Challis Planning Unit," is a series of calculations for estimating forage intake for big game in Idaho. It cites a number of personal communications and a few dated papers to support the forage intake rates given. The validity of these figures is not a question here, even though no evidence is given to substantiate the intake values for big game given in the memorandum.

Henceforth, intake rates taken from this memo will be referenced to the State Director, Idaho (1978).

The memo in question does emphasize that the forage intake rates given apply to southern Idaho districts and do not pertain to northern portions of the state.

3.4 Pronghorn Antelope

Three forage intake rates for pronghorn antelope (*Antilocapra americana*) are shown in Table C9. The average of the three rates is 1.8 pounds (0.82 kg)

Table C7. Summary of forage intake rates for bison.

ANIMAL	FEED OR PASTURE TYPE	BODY WEIGHT lbs	BODY WEIGHT kg	MBW[a] (kg)	MBW exponent	FORAGE INTAKE (animal^{-1}day^{-1}) lbs	kg	g/kgMBW	% BW	REPORTED as	REMARKS	SEASON	LOCATION	REFERENCE
Bison	Shortgrass prairie	767.3	348	80.5	0.75	13.4	6.1	75.8	1.74		Heavy and light grazing average of three animals	Summer	NE Colorado	Rice et al. 1974

[a] metabolic body weight

Table C8. Summary of forage intake rates for bighorn sheep.

ANIMAL	FEED OR PASTURE TYPE	BODY WEIGHT lbs	BODY WEIGHT kg	MBW(kg)[a)]	MBW[a)] exponent	FORAGE INTAKE (animal^{-1}day^{-1}) lbs	FORAGE INTAKE kg	FORAGE INTAKE g/kgMBW	FORAGE INTAKE % BW	REPORTED as	REMARKS	SEASON	LOCATION	REFERENCE
Bighorn Sheep	Concentrate	150	68.0	23.7	0.75	2.9	1.3	54.8	1.9			Winter		Chappel & Hudson 1978
Bighorn Sheep	Rangeland	124	56.2	20.5	0.75	3.9	1.8	86.3	3.2				Idaho	State Director, Idaho 1978

a) metabolic body weight

Table C9. Summary of forage intake rates for pronghorn antelope.

ANIMAL	FEED OR PASTURE TYPE	BODY WEIGHT lbs	BODY WEIGHT kg	MBW(kg)[a)]	MBW[a)] exponent	FORAGE INTAKE ($animal^{-1}day^{-1}$) lbs	kg	g/kgMBW	% BW	REPORTED as	REMARKS	SEASON	LOCATION	REFERENCE
Antelope	Native forage	90.0	40.8	16.1	0.75	1.7	0.8	49.7	1.9				Wyoming	Severson et al. 1968
Antelope	Concentrate	90.0	40.8	16.1	0.75	2.0	0.9	56.3	2.2				Colorado	Wesley et al. 1973
Antelope	Native forage					1.8					Body weight not specified		Idaho	State Director, Idaho 1978

a) metabolic body weight

of forage intake animal^{-1}day^{-1}. One value comes from the State Director of Idaho (1978) and is an estimate not based on direct measurement. The other two intake values of 1.7 and 2.0 pounds of forage intake per animal^{-1}day^{-1} come from Severson et al. (1968) and Wesley et al. (1973) respectively. Both were studies that used penned animals. Severson and co-workers offered caged animals fresh-cut native forage. Wesley et al. (1973) used concentrate feed in pellet form as forage. The intake rates from all three sources are within the values considered valid by Cordova et al. (1978) in their review article for grazing livestock in the United States. (That range is from 1 to 2.8% of body weight and from 40 to 90 grams per kilogram of metabolic body weight.) Remember however, that the pronghorn antelope feeds primarily on browse while the sheep and cattle studies considered by Cordova et al. (1978) utilize grasses and some forbs. The correspondence between consumption rates for browsers and grazers then, is somewhat tenuous.

3.5 Mule Deer and White-Tailed Deer

Forage intake rates for mule deer (*Odocoileus hemionus*) and white-tailed deer (*Odocoileus viginianus*) are reported in Table C10.

Alldredge et al. (1974) used fallout Cesium-137 concentrations in native forage and in killed mule deer to derive forage intake and retention functions. The mean forage intake rate of 21.9 grams air dry forage per kilogram carcass weight per day came from 87 mule deer collected over a two year period. Note is made here that this value of forage intake is inferred rather than measured.

Wallmo et al. (1977) use Alldredge et al. (1974) methodology and functions to derive the carrying capacity for deer on a seasonal range in Colorado. Again, this study was not a direct measurement of forage intake rates.

The average of the forage intake rate from the Alldredge et al. (1974) and the Wallmo et al. (1977) studies is 1.5 $\pm$ 0.45 kg animal^{-1}day^{-1} or 64.3 $\pm$ 12.8 grams per kilogram MBW animal^{-1}day^{-1} or 2.3 $\pm$ 0.59 percent body weight animal^{-1}day^{-1}. The fawn average forage intake rate from the Wallmo et al. (1977) study for the entire winter is 72.6 g/kg MBW animal^{-1}day^{-1}, while winter rates for males and females were 59.1 and 56.1 g/kg MBW animal^{-1}day^{-1}.

The intake rates tabulated in Table C10 are derived from estimates except for the work of Nichol (1938), Nagy et al. (1969) and Carpenter and Baker (1975). All of the studies deal with the genus *Odecoileus*. None explicitly state forage intake rates for white-tailed deer; only mule deer. Several studies have been made in the eastern United States with penned white-tailed deer but are not included in the present review which emphasizes western rangeland conditions.

3.6 Elk

Forage intake rates for elk (*Cervus canadensis*) are summarized in Table C11. Of interest here is that but for two measurements, forage intake for elk has been measured or estimated for the winter season or months only. The

Table C10. Summary of forage intake rates for deer.

ANIMAL	FEED OR PASTURE TYPE	BODY WEIGHT lbs	BODY WEIGHT kg	MBW(kg)[a]	MBW[a] exponent	FORAGE INTAKE ($animal^{-1} day^{-1}$) lbs	kg	g/kgMBW	% BW	REPORTED as	REMARKS	SEASON	LOCATION	
Mule deer	Native forage	135	61.2	21.9	0.75	2.7	1.2	54.8	2.0		2 year study	Yearly	Colorado	Alldredge et al. 1974
Mule deer	Alfalfa hay	135	61.2	21.9	0.75	3.4	1.5	68.5	2.5			Winter	Utah	Doman & Rassmussen 1944
Mule deer	Whole barley Alfalfa hay	135	61.2	21.9	0.75	4.8	2.2	99.5	3.6			Winter	Utah	
Mule deer	Native forage	135	61.2	21.9	0.75	4.2	1.9	87.0	3.1				Idaho	State Director, Idaho 1978
Deer	Native forage	135	61.2	21.9	0.75	2.4	1.1	49.7	1.8					Carpenter & Baker 1975
Deer	Native forage	135	61.2	21.9	0.75	3.2	1.5	68.5	2.4					Nichol 1938
Deer	Alfalfa hay	135	61.2	21.9	0.75	2.7	1.2	54.8	2.0		Good quality feed			Nagy et al. 1969
Deer	Alfalfa hay	135	61.2	21.9	0.75	0.7	0.3	13.7	0.5		Poor quality feed			
Deer	Native hay	135	61.2	21.9	0.75	0.6	0.3	13.7	0.4		Poor quality feed			
Yearling females	Native forage	141	64	22.6	0.75	4.4	2.0	84.5	3.1			Summer	Colorado	Wallmo et al. 1977
Yearling males	Native forage	154	70	24.2	0.75	4.9	2.2	90.9	3.1			Summer	Colorado	
Adult females	Native forage	154	70	24.2	0.75	3.3	1.5	62.0	2.1			Summer	Colorado	
Adult males	Native forage	205	93	29.9	0.75	4.4	2.0	66.9	2.2			Summer	Colorado	
Fawns	Native forage	55	25	11.2	0.75	1.8	0.8	71.4	3.2			Early Winter	Colorado	
Yearling females	Native forage	143	65	22.9	0.75	3.5	1.6	69.9	2.5			Early Winter	Colorado	
Yearling males	Native forage	187	85	28.0	0.75	4.4	2.0	71.4	2.4			Early Winter	Colorado	
Adult females	Native forage	161	73	25.0	0.75	3.1	1.4	56.0	1.9			Early Winter	Colorado	
Adult males	Native forage	243	110	34.0	0.75	4.6	2.1	61.8	1.9			Early Winter	Colorado	
Fawns	Native forage	62	28	12.2	0.75	2.0	0.9	73.8	3.2			Late Winter	Colorado	
Yearling females	Native forage	141	64	22.6	0.75	2.4	1.1	48.7	1.7			Late Winter	Colorado	
Yearling males	Native forage	172	78	26.2	0.75	2.9	1.3	49.6	1.7			Late Winter	Colorado	
Adult Females	Native forage	154	70	24.2	0.75	2.6	1.2	49.6	1.7			Late Winter	Colorado	
Adult males	Native forage	205	93	29.9	0.75	3.5	1.6	53.5	1.7			Late Winter	Colorado	

a) metabolic body weight

Table C11. Summary of forage intake rates for elk.

ANIMAL	FEED OR PASTURE TYPE	BODY WEIGHT lbs	BODY WEIGHT kg	MBW[a] (kg)	MBW[a] exponent	FORAGE INTAKE (animal^{-1} day^{-1}) lbs	kg	g/kgMBW	% BW	REPORTED as	REMARKS	SEASON	LOCATION	REFERENCE
Calves	Pelleted ration							112.8		DMI	Body weight not specified	October	Canada	Westra & Hudson 1979
	Pelleted ration							91.1		DMI	Body weight not specified	December	Canada	
	Pelleted ration							82.7		DMI	Body weight not specified	February	Canada	
	Pelleted ration							71.8		DMI	Body weight not specified	April	Canada	
	Pelleted ration							79.6		DMI	Body wieght not specified	June	Canada	
Elk	Native grass	400	181.4	49.4	0.75	9.2	4.7	95.1	2.3			Winter	Montana	Geis 1950
	Meadow hay	400	181.4	49.4	0.75	8.4	3.8	76.9	2.1			Winter	Montana	
	Browse (willow)	400	181.4	49.4	0.75	8.7	3.9	78.9	2.2			Winter	Montana	
	Hay-browse mix	400	181.4	49.4	0.75	13.1	5.9	119.4	3.3			Winter	Montana	
Elk	Grass hay	400	181.4	49.4	0.75	10.7	4.9	99.2	2.7			Winter	Idaho	Hungerford 1948
	Native grass	400	181.4	49.4	0.75	10.4	4.7	95.1	2.6			Winter	Idaho	
	Browse (willow, serviceberry, maple)	400	181.4	49.4	0.75	8.8	4.0	81.0	2.2			Winter	Idaho	
Elk	Grass hay	400	181.4	49.4	0.75	12.5	5.7	115.4	3.1					Murie 1951
Elk	Grass hay	400	181.4	49.4	0.75	10.0	4.5	91.1	2.5			Winter	Colorado	Robbins 1973
	Alfalfa hay	400	181.4	49.4	0.75	8.0	3.6	72.9	2.0			Winter	Colorado	
Elk	Grass hay	400	181.4	49.4	0.75	9.1	4.1	83.0	2.3					Thorne et al. 1976
Calves		250				2.5(CWT)[b]							Idaho	State Director, Idaho 1978
Cows		500				2.0(CWT)							Idaho	
Yearling		350				2.3(CWT)							Idaho	

[a] metabolic body weight

[b] per hundred pounds body weight

rates for April and June reported by Westra and Hudson (1979) are for calves and not adult animals. All measurements were feeding trials. The average forage intake rate reported by Thorne et al. (1976), Robbins (1973), Murie (1951), Hungerford (1948), and Geis (1950) is 4.5 $\pm$ 0.8 kg animal^{-1}, 91.6 $\pm$ 15.3 g/kg MBW animal^{-1}day^{-1}, or 2.5 $\pm$ 0.4 percent body weight.

3.7 Horses and Burros

Table C12 summarizes the forage intake rates for horses (*Equus cabalus*) and burros (*Equus asinus*). As will be noted, only one consumption rate is given for burros. It is by Koehler (1974), from his masters thesis which dealt with an area in New Mexico. The figure reported for burros is not based on any precise measurement but on observation alone.

The study by Darlington and Hershberger (1968) used penned ponies, fed the indicated feed harvested on 3 separate dates in June, each harvest carried out on a different pasture. The average of the range midpoints for all three seasons and all three feed types is 82g/kg MBW animal^{-1}day^{-1}.

Fonnesbeck (1968) was concerned with water intake in horses fed combinations of grass hay and grain. The mean of the forage intake rates reported in this study was 7.1 $\pm$ 1.3 kg animal^{-1}day^{-1} or 75.4 $\pm$ 13.3 g/kg MBW animal^{-1} day^{-1} or 1.7 $\pm$ 0.3 percent body weight. The large standard errors here are due to the fact that intake decreases if the nutritional quality of the feed is increased, as it is with the addition of grain to the grass hay.

Table C12. Summary of forage intake rates for horses and burros.

ANIMAL	FEED OR PASTURE TYPE	BODY WEIGHT lbs	BODY WEIGHT kg	MBW[a] (kg)	MBW[a] exponent	FORAGE INTAKE (animal^{-1}day^{-1}) lbs	FORAGE INTAKE kg	FORAGE INTAKE g/kgMBW	FORAGE INTAKE %BW	REPORTED as	REMARKS	SEASON	LOCATION	REFERENCE
Pony	Alfalfa	312	141.5[b]	41.0	0.75			65-95		DMI	Intake range for three harvest dates	June	Pennsylvania	Darlington & Hershberger 1968
	Timothy	312	141.5	41.0	0.75			82-87		DMI	Intake range for three harvest dates			
	Orchardgrass	312	141.5	41.0	0.75			79-82		DMI	Intake range for three harvest dates			
Horse	Bermudagrass	946	429[b]	94.3	0.75	17.8	8.07	85.6	1.9				New Jersey	Fonnesbeck 1968
	Bromegrass	946	429	94.3	0.75	17.5	7.94	84.2	1.9					
	Canarygrass	946	429	94.3	0.75	16.8	7.64	81.0	1.8					
	Fescue	946	429	94.3	0.75	16.7	7.56	80.2	1.8					
	Timothy	946	429	94.3	0.75	17.6	7.99	84.7	1.9					
	Alfalfa	946	429	94.3	0.75	19.1	8.67	91.9	2.0					
	Red clover	946	429	94.3	0.75	18.7	8.48	89.9	2.0					
	Orchardgrass	946	429	94.3	0.75	18.4	8.36	88.7	2.0					
	Corn-alfalfa	946	429	94.3	0.75	13.5	6.10	64.7	1.4					
	Barley-alfalfa	946	429	94.3	0.75	12.5	5.67	60.1	1.3					
	Oats-alfalfa	946	429	94.3	0.75	14.8	6.71	71.2	1.6					
	Corn-canarygrass	946	429	94.3	0.75	12.5	5.65	59.9	1.3					
	Barley-canarygrass	946	429	94.3	0.75	12.7	5.74	60.9	1.3					
	Oat-canarygrass	946	429	94.3	0.75	11.0	4.98	52.8	1.2					
Burro	Native forage					11.0	5.0				Animal weight not specified		New Mexico	Koehler 1974

[a] metabolic body weight

[b] midpoint of reported range

4.0 ESTIMATES FOR USE IN FORAGE ALLOCATION MODELS

The survey of the scientific literature which pertains to the forage intake rates of large herbivores has shown that there are a number of instances where the forage intake rates required for use in the optimization of forage allocation models (Chapter A) are not available. Still, those models do require estimates of forage intake: When the index k in equation (1) (Section 1.0) is considered, seasonal forage intake rates are required. Those rates do not appear in the literature for wildlife. This section establishes provisional forage intake rates which can be used to test the above mentioned models.

A question arises as to which method of reporting forage intake rates to use, organic matter or dry matter intake. Buchanan et al. (1972) working with sheep in Montana found that, over the summer at least, dry matter intake remained almost constant while green weight fell precipitously. Van Dyne et al. (1980) in their consideration of forage intake for cattle and sheep on a world-wide scale converted intake rates they tabulated exclusively into dry matter values. Table C13 compares the differences between organic matter intake and dry matter intake in percent of live body weight for cattle and sheep. Cattle used more dry matter in the spring than in the summer or fall/winter and more in the summer than in the fall/winter period. Sheep consumed approximately the same amount of forage in all seasons for which data was available. (If only one entry for a season was tabulated in Tables C2 or C4, it was omitted from the compilations shown in Table C13. Where the method of reporting was not specified in Tables C2 and C4, entries were assumed to be dry matter intake.) Table C13 is for grazing trials only, and because of some assumptions and the ways in which the data were treated, differs from a similar table in Van Dyne et al. (1980). Data in Table C13 are for grazing trials from rangelands in western North America and Australia and from pasture studies in Great Britain. These values are somewhat lower than the organic matter intake values summarized from the world literature by Van Dyne et al. (1980) and somewhat higher than the dry matter intake values they reported. The data in Table C13 are based on more examples than in the Van Dyne et al. (1980) summarization for sheep forage intake on an organic matter basis but on fewer examples in other situations. Table C13 shows that dry matter intake is higher for all corresponding seasons than is organic matter intake.

Since dry matter intake (or unknown) entries predominate in the cattle and sheep consumption rate tables (Tables C2 and C4) presented herein, dry matter intake values are used for testing forage allocation models. Table C14 presents those values. Where seasonal or grazing trial information is missing, the average or only value tabulated is shown. The optimization models require intake rates in kilograms animal^{-1}day^{-1}. Values for use in the models are presented in Table C14 with those units. Considering both variation among animals in a trial and variation among trials due to methodological and situational differences, the coefficient of variation of forage intake is about 20% for large herbivores. Within a trial, and therefore with methodology and situation fixed, the coefficient of variation in forage intake appears to be near 33% for cattle and 21% for sheep (Van Dyne 1965). These values compare to coefficients of variation for fecal excretion rate, cellulose concentration in feces, digestibility of cellulose, and diet concentration of cellulose of 30, 8, 6, and 4% for sheep and 11, 7,

Table C13. Forage intake rates for cattle and sheep according to season, presented as percent of live body weight.

SPECIES	SEASON	ORGANIC MATTER BASIS MEAN±S.D. (N)	SEASON	DRY MATTER BASIS MEAN±S.D. (N)
Cattle	Spring	2.1±0.39 (2)	Spring	2.8±0.55 (4)
	Summer	1.9±0.54 (5)	Summer	2.3±0.60 (19)
	All Seasons Combined	2.2±0.62 (12)	Fall/Winter	1.5±0.56 (3)
			All Seasons Combined	2.2±0.59 (26)
Sheep	Summer	2.1±1.20 (2)	Spring	2.6±0.26 (9)
	All Seasons Combined	1.7±0.58 (10)	Summer	2.4±0.40 (15)
			Winter	2.3±0.54 (16)
			All Seasons Combined	2.4±0.50 (33)

Table C14. Estimates of forage intake for use in optimization of forage allocation models by species of herbivore and by season. All entries are in units of kilograms animal day followed by a standard deviation of the number of values reported where greater than one.

HERBIVORE	SEASON			
	SPRING	SUMMER	FALL	WINTER
Cattle	8.2±1.61 (4)	7.6±2.83 (29)	8.18 (1)	4.4±1.48 (2)
Sheep	1.5±0.16 (9)	1.4±0.35 (14)	1.4 (1)	1.4±0.39 (14)
Bison	6.1 (1)	6.1 (1)	6.1 (1)	6.1 (1)
Bighorn Sheep	1.6±0.35 (2)	1.6±0.35 (2)	1.6±0.35 (2)	1.6±0.35 (2)
Pronghorn Antelope	0.8±0.07 (2)	0.8±0.07 (2)	0.8±0.07 (2)	0.8±0.07 (2)
Deer	1.9±0.29 (4)	1.9±0.29 (4)	1.9±0.29 (4)	1.9±0.29 (4)
Elk	4.5±0.76 (11)	4.5±0.76 (11)	4.5±0.76 (11)	4.5±0.76 (11)
Horses	7.1±1.25 (14)	7.1±1.25 (14)	7.1±1.25 (14)	7.1±1.25 (14)
Burros	5.0 (1)	5.0 (1)	5.0 (1)	5.0 (1)

10, and 3% for cattle in the same study. Thus, because forage intake rate estimates are derived from several properties of fecal output, diet and feces chemical composition, and diet digestibility, the variability in estimates of forage intake rate are high.

5.0 CONCLUSIONS

The compilation of this chapter has shown that there is an interest in forage intake rates among researchers and natural resource management agencies. Of real concern is the dearth of information on consumption rates for wildlife and feral horses and burros. True, there is some information available on intake for non-domestic herbivores but the information is anecdotal, derived from inferences (c.f. Alldredge et al. 1974), or ascertained from conventional feeding trials of penned animals (Tables C6, C8-C12).

From Table C7, it will be noted that only one measure of forage intake for bison is reported and that only for the summer season. Table C12 for equine shows only one entry for burro forage intake rate. It was derived by direct observation. The other values for feeding trial forage intake rate reported herein largely avoid the complication of season. The cages or pens were not necessarily kept out-of-doors, hence the influence of climate variations, including temperature and photoperiod, were not considered in the experimental design. It is therefore somewhat doubtful that much attention should be paid to the feeding trial information as regards season.

Even the field grazing trial information is limited in its generality. While Tables C2 and C4 show forage intake rates for cattle and sheep in various of the four seasons, some entries are not values obtained in the United States. Those values for forage intake reported by the U.S. workers do not encompass enough of the grasslands or rangelands of the country to provide the needed information. Figure C9 is illustrative of this. That figure shows no pasture or grazing trials for any wildlife save one study for bison in northeast Colorado. Note the absence of studies of domestic herbivores in Montana, Idaho, North and South Dakota, Washington and Arizona. The Georgia work was on a wiregrass pine range and has scant applicability to prairie and western rangeland concerns.

Since forage allocation models in use or under consideration for use by natural resource management agencies require information at least at the allotment level of resolution (sometimes even smaller), grazing trial derived forage intake rates gathered in one part of a state or district or country cannot be considered representative of rates elsewhere. Specific recommendations and information needs are as follows: Rangeland grazing trials are incomplete for domestic herbivores and absent for wildlife and equine. Specific areas and locales where substantial management concerns exist need to be identified. Factors to be considered in these determinations are herbage composition, rangeland condition and phenological development of the forage species. Herbivores, both wild and domestic, that use the forage in the specific locale need to be ascertained. Then, standards as to sex, age, physiological status and number for each herbivore species need to be established so that forage intake rate studies can be undertaken. Methods of measurement and reporting of forage intake results, likewise need to be standardized.

Once such procedures have been established, a subsequent compilation much like this could then be written but without the qualifications and stipulations contained herein. It is realized that such procedural and experimental effort as outlined above will entail the expenditure of large amounts of capital.

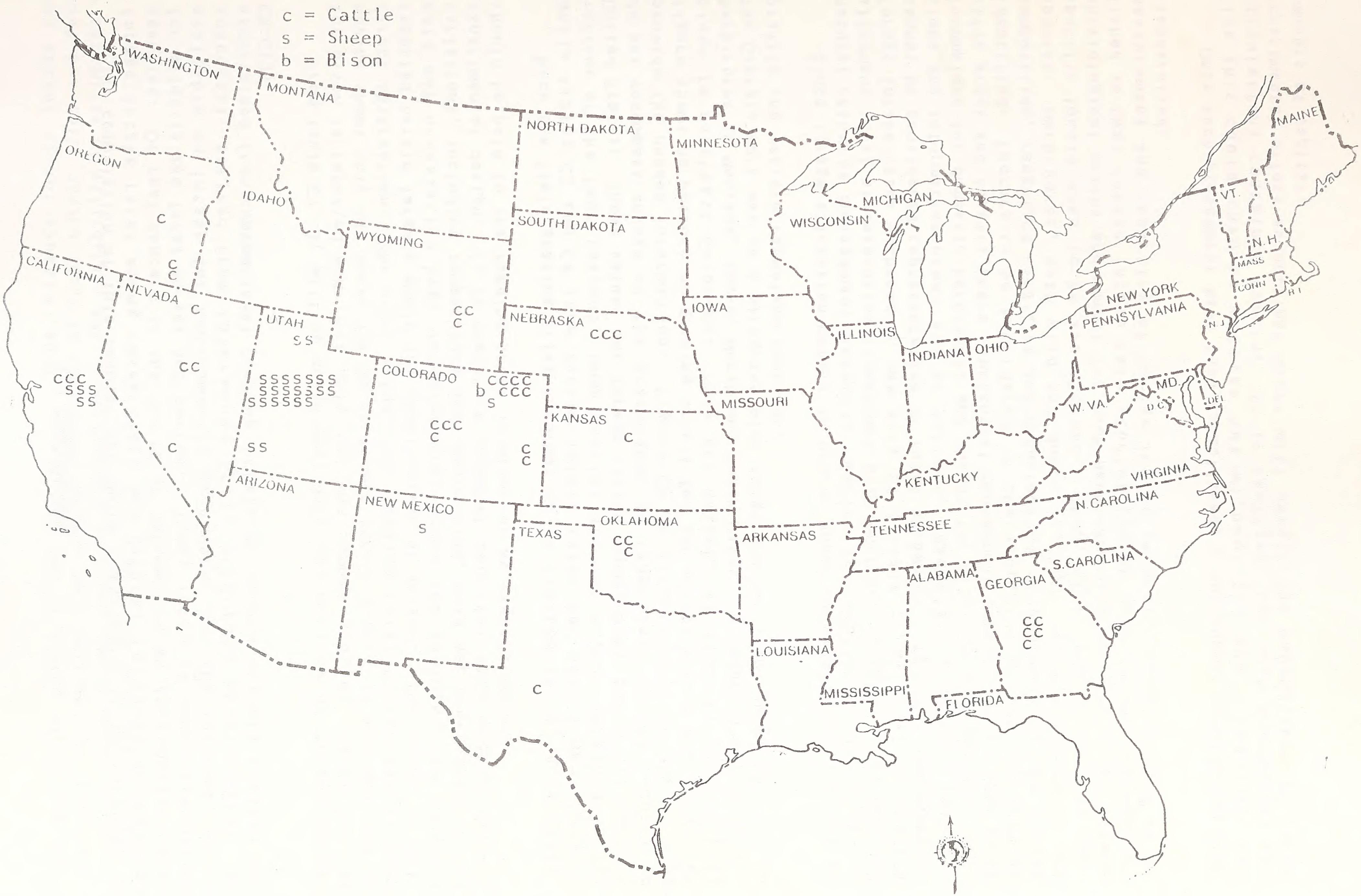

Figure C9. Approximate geographical location of grazing trial studies of forage intake rates. Each occurrence of a symbol reflects an entry for consumption in Tables 2, 4, and 7.

Still, a major conclusion of this chapter is that forage intake rate studies have not been done for many species of herbivore according to locale and season.

Our review has yielded forage intake rates for various conditions. Averaged overall and expressed as kilograms animal^{-1}day^{-1} they are as follows: cattle, 7.5; sheep, 1.4; bison, 6.1; bighorn sheep, 1.6; pronghorn antelope, 0.8; deer, 1.9; elk, 4.5; horses, 7.1; and burros, 5.0. The mean live body weight in kilograms in the example studies reviewed and the forage intake as percent body weight are: cattle, 343.1 and 2.2; sheep, 55.6 and 2.2; bison, 348 and 1.7; bighorn sheep, 62.1 and 2.6; pronghorn antelope, 40.8 and 2.1; deer, 66.9 and 2.2; elk, 181.4 and 2.4; horses, 378.3 and 1.7. Burro body weight was not reported, hence no values are available.

The above averaged data appear somewhat disparate in their present form. To enable some comparison of these data they were transformed into animal unit equivalents (AUE). A standard of a 454 kg (1000 lb.) animal was used. That standard raised to the 0.75 power divided into our averaged body weight for a given animal raised to the 0.75 power yields the animal unit equivalent. The relation is:

$$AUE = W_{kg}^{0.75}/454^{0.75}.$$

The AUE has no units since they cancel in the calculation. The AUE divided into forage intake in kilograms per animal per day gives a value normlized to the standard 454 kg animal. If this last value is multiplied by 2.2, the result is intake in pounds per animal per day normalized to the 1000 lb animal standard. Table C15 presents the data so manipulated. The final two columns are forage intake in units of kilograms and pounds respectively per AUE.

It will be noted that normalized intake rates range between about 15 to 20 pounds per day for all herbivores with the exception of pronghorn antelope which is about 11 pounds per day. This latter reflects the small body weights and small intake rates we found in the literature. (See section on forage intake rates for pronghorn antelope earlier in this chapter.)

Table C15. Comparison of forage intake rates per animal unit equivalent for nine herbivore species.

Herbivore	Body Weight (kg)	Forage Intake ($kg\ d^{-1}$)	AUE[a]	Intake/AUE (kg)	Intake/AUE (lbs)
Cattle	343.1	7.5	0.81	9.26	20.37
Sheep	55.6	1.4	0.21	6.67	14.67
Bison	348.0	6.1	0.82	7.44	16.37
Bighorn Sheep	62.1	1.6	0.22	7.27	15.99
Pronghorn Antelope	40.8	0.8	0.16	5.00	11.00
Deer	66.9	1.9	0.24	7.92	17.42
Elk	181.4	4.5	0.50	9.00	19.80
Horses	378.3	7.1	0.87	8.16	17.95
Burro	--	5.0	--	--	--

[a] Animal unit equivalent

CHAPTER D

A CRITICAL REVIEW AND EVALUATION OF DIETARY BOTANICAL COMPOSITION

ABSTRACT

There are several methods used to determine dietary botanical composition of herbivores reported in the literature. The principal factors affecting diet composition are phenological stage and geographical area. The principle methods for estimating diet composition are the use of fistulated animals, fecal analysis, ocular bite counts and clipping. The use of fistulated animals, a direct form of measurement, is the most accurate while clipping, an indirect form of measurement, is the least accurate means of estimating diet composition. Analysis of fecal or forage samples by microscopic determination is difficult and requires a good collection of reference slides and trained technicians. Analysis of fecal samples by microscopic methods is further complicated in that many plants are hard to recognize at this stage of degradation. Furthermore, there is differential digestibility of different groups of plants as they pass through the digestive tract of the animal, thus leading to bias in results obtained from fecal analyses. In this chapter we compile information on the dietary botanical composition of large herbivores. We summarize previously unpublished data obtained from the Bureau of Land Management and we condense from 137 scientific references information about the diets of animals. The animals concerned include cattle, sheep, bison, bighorn sheep, pronghorn antelope, mule deer, whitetailed deer, elk, horses, and feral burros. In these compilations we report the data for plant species which are 5% or more of the diets in quantitative terms and for plant species which are less than 5% of the diets simply a listing is given. We identify the location of the study, the season of the year, management and treatment information is given, and classify the plants as to belonging to the C_3 or C_4 pathway of photosynthesis and hence growth season.

CHAPTER D

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1.0 INTRODUCTION

The purpose of the grazing allocation model is to maximize the utilization of range forage production, subject to biological constraints. A mathematical model, regardless of how complex or detailed it is, can only be as reliable or accurate as the data driving the model and the underlying assumptions of the model.

Several relative diet preferences are discussed by Krueger (1972). One such preference index is required in all of the optimization models being considered (Chapter A), and is used to predict the proportional amount of each relevant species or functional group grazed by each of the herbivores considered (bighorn sheep, bison, cattle, elk, muledeer, white-tailed deer, pronghorn antelope, sheep, wild horses and burros). A relevant plant species or group is considered to be one that comprises 5 percent or more of the dietary botanical composition of the herbivore. Thus, the optimization models address this "range use efficiency problem" by solving for the optimal combination of herbivores to graze based on a preliminary estimation of the composition of available herbage and predictions of dietary botanical composition, intake rate, and loss and gains in the standing crop. The optimal combination of herbivores is one that, for our formulation, makes the most use of the herbage and hence produces the most animal unit equivalents, so that the estimated allowable herbage available is fully utilized by the herbivores.

This chapter presents a critique of the methods used in determining the dietary botanical composition of the large herbivore species and a compilation of studies that have estimated dietary botanical composition by employing some of the various methodologies discussed in this report.

2.0 SELECTIVE GRAZING

If herbivores simply grazed the available herbage non-selectively, then dietary botanical composition would directly follow in the same proportions as the proportional composition of the available forage. However, selective grazing markedly alters dietary botanical composition of forage ingested relative to herbage available on native rangelands (Galt et al. 1968). Range species that may be available in only trace amounts may be a major component of the herbivores' diet, while the major plant species of the range are not necessarily major components of the herbivores' diet.

In fact, not only is selective grazing apparent, but the forage species selected by cattle for instance, can change rapidly in as little as a three week period, while herbage species composition remains relatively constant (Theurer 1973). Consequently, not only is one unable to directly infer dietary botanical composition from native range composition, it is apparent that neither can one determine dietary preference solely from range composition.

The two principal factors that affect dietary botanical composition are phenological sensonality and geographical location. These factors affect availability or composition of forage species through the quantity or size of standing crop, the quality or palatability of the plant species and the forage availability due to snow cover or size. These site and herbage dependent factors are further complicated by herbivore dependent factors such as competition, both interspecific and intraspecific and the nutritional requirements of each herbivore species. These factors have their affect on the herbivores' preference for different plant groups (Van Dyne et al. 1980).

When examining average annual dietary botanical composition, the standard error of the means tends to be as large or larger than the means (Van Dyne et al. 1980). In the case of the above workers, one third of the estimated plant groups had standard errors equal to or greater than their means. Even when seasonality was accounted for, it did not greatly reduce the degree of variability in the data since more than one-half of the means still had standard errors equal to or greater than their repsective means. When changes in seasonality are considered along with partitioning locations to the level of a proportionally relatively homogeneous range composition, then more pronounced significant differences can be shown (McReynolds 1977).

Wentlands (1968) has shown that over different years in the same location and with relatively the same forage availability, dietary botanical composition can change greatly. Kautz and Van Dyne (1978) combined plant species into five functional groups to statisically analyze the influence of herbivore species, competition through grazing intensity, season of grazing and the interactions between these treatments. There were highly significant differences among herbivore species, between grazing intensities and between seasons in the herbivore's dietary botanical composition of warm-season forbs, cool-season forbs and shrubs. There were also highly significant differences in the herbivore species' diets of warm-season grasses. These findings show that significant differences in herbivore preference and/or forage availability occur in all of the plant groups except cool-season grasses, necessitating a thorough understanding of differences in dietary botanical composition of large herbivores if efficient use is to made of the nation's grazinglands.

3.0 METHODS FOR ESTIMATING DIETARY BOTANICAL COMPOSITION

There are a number of methods used in estimating dietary botanical composition of large herbivores. These include the use of fistulated animals both rumen fistulas (Lesperance et al. 1960) and esophageal fistulas (Torell 1954), fecal analysis (Free et al. 1970, Vavra et al. 1970, Hansen et al. 1973), ocular bite counts (Reppert 1960), plot clippings and direct observation of wild and tame animals.

3.1 Fistulated Animals

The use of esophageal or rumen fistulated animals appears to be the most accurate method available to estimate dietary botanical composition (Rice et al. 1971, Smith and Shandruk 1979, Vavra et al. 1978). The advantages of rumen or esophageal content analysis are that there is little doubt an ingested item is in fact forage and, according to Medin (1970), animal populations can be sampled over time and within age and sex groups.

The disadvantages of using fistulated animals for diet composition studies are several. Differential rates of digestion, especially in rumen content analyses, biases results toward the less digestible items (Norris 1943, Bergerud and Russell 1964). Forage items can remain in the rumen for periods of days after ingestion. Consequently it is not always possible to infer that the animal fed in the area where the collections were made. (This may not be so with the rumen clearance method.) Anderson et al. (1965) maintain that at least 70 samples must be collected to estimate, within acceptable error limits, diverse diets. And, according to Courtwright (1959) larger plant fragments in samples are identifiable yet they represent only small portions of the total sample: Any assumption that the unidentifiable plant parts represent the identified plants is unfounded.

Examinations of the extrusa of fistula forage samples can be done by a variety of techniques. The hand separation method (Stobbs 1969) and the microscopic point method (Heady and Torrell 1959, Galt et al. 1968) which has been improved upon through the use of regression models for predicting weight composition (Heady and Van Dyne 1965), tend to examine only the larger plant fragments. The microscope method, a less time consuming version of the microscopic point method (Sparks and Malecheck 1968), and liquid masceration method (Marshall and Squires 1979) examine all plant fragments.

Proponents of the microscope point method claim that with 400 observed microscope points, the average weight of a species can be estimated within 5 percent of the mean at a 90 percent level of probability when the species constitute 30 to 60 percent of the sample weight (Galt et al. 1968). However, this degree of statistical confidence is associated with macerated material and not the extrusa of rumen or esophageal fistulated herbivores.

When diets of known composition where fed to sheep, Marshall and Squires (1979) reported that large differences between the estimated and known composition where observed. Generally there was a tendency to overestimate grasses and to underestimate forbs. While none of the methods appear to be the most accurate, the microscope method has the greatest amount of error associated with it. The error associated with each of the methods represents a bias in the observed data that varies with each different mixture of species in the dietary botanical composition of the herbivore.

In a study of all four methods using extrusa of esophageal fistulated animals, Marshall and Squires (1979) concluded that the "hand separation and the microscopic methods are only sufficiently reliable to allow estimation of dietary composition to within broad catagories defined as minor (less than 20%), moderate (the range of 21 to 50%) and major (greater than 50%) proportions." Although a relationship exists between known and estimated dietary compositon, the relationship changes with variations in known composition, further complicating the type and degree of bias associated with the observed data.

While studies of the extrusa of fistulated animals can give the most direct representation of a herbivore's diet, these animals can exhibit abnormal behavior.

3.2 Fecal Analysis

There are several advantages to using fecal analysis for determination of dietary botanical composition. The method is quick and relatively inexpensive and specific habitat sampling with established levels of precision is possible. It also has the advantage of virtually unlimited numbers of samples available, any of which may be obtained without disturbance to the animals under study.

As with samples taken from fistulated animals, fecal samples do not lend themselves to easy identification of the dietary botanical composition through microscopic analysis of plant remants. Species recognition characteristics vary greatly between forage species and between groupings of forage classes (Vavra et al. 1978, Smith and Shandruk 1979, Zynur and Urness 1969). The ramifications of this disadvantage can lead to confusion. In his study of bighorn food habits, Johnson (1979) determined that Polygonum bistortoides and Vaccinium scoparium were important (summer) forages, yet the fecal analysis done in his study failed to identify any of those plant species in bighorn feces. Fecal analysis done for the study by Howard and DeLorenzo (1975) showed an average of 49% of Chilopsis sp. during the spring months and 23% of Chilopsis sp. during the summer months in bighorn sheep diets. Those authors however, found no Chilopsis sp. in any of their vegetation transects nor in any of the primary sheep habitats. Indeed, Chilopsis sp. was found only in trace amounts in the riparian habitat that was not frequented by the bighorn sheep. These two studies lead one to doubt the accuracy of any plant identification from feces, certainly, at least, in bighorn sheep studies.

Fecal analysis is also subject to bias induced by differential digestion rates of plant material (Slater and Jones 1971, Takatsuki 1978). When esophageal fistula data is compared to fecal material data the same relationships exist between esophageal and fecal samples as between esophageal samples and known diet composition, although with considerably more variation (Vavra et al. 1978). Fecal analysis studies show that total grasses are significantly overestimated while total forbs are significantly underestimated. Due to the greater variation of fecal material samples, correlation and regression analysis revealed no significant relationship between esophageal and fecal samples in determining dietary botanical composition.

There is yet to be reported in the literature a study in which diets of known composition are fed to fistulated animals and both the extrusa of fistulated animals and their fecal samples are analyzed for the purpose of comparing them to the known diet composition. With a knowledge of reported differences between esophageal fistula samples and known diet composition (Marshall and Squires 1979), and reported differences between esophageal fistula samples and fecal samples (Vavra et al. 1978), one may make inferences with a calculated example of differences between actual diet composition and analyzed fecal material. There appear to be two significant biases that enter this kind of data regardless of the technique employed: differential digestibility, a major source of bias which is primarily due to cell wall thickness of plant fragments and differential recognizability due to the degree of maceration and digestion which is also a bias as well as a prime source of variation.

Assume, for the sake of agrument, that the bias of differential digestion explains fully the differences between known diets and esophageal fistula samples. Further consider that the differences between fistulated samples and fecal samples represent the degree of unrecognizability due to differing levels of maceration and digestion and constitute a large source of variation as well as a significant bias as the data seems to suggest. Further, consider that because all reported data are expressed in relative proportions, that such estimated proportions are interdependent variables. Thus, whenever a technician overestimates or underestimates one plant species, the proportions of other species in the sample are adjusted upward or downward by an equivalent amount. This can be seen when the relative contributions are normalized to estimated percent diet composition. From the data in Table D1 one can see how differences in indigestibility and recognizability can exhibit strong bias on estimated diet composition. The indigestibility coefficients (Table D1) are derived from the regression models of Marshall and Squires (1979) and represent a bias more than a source of variability. The recognizability coefficients are more arbitrary since they were picked in order to give both the expected results and variability of reported differences of Vavra et al. (1978) between esophageal analysis data and fecal analysis. The example model suggests that in order to get a high degree of variability and bias between esophageal and fecal samples, the degree of differences between the recognizability coefficients of plant species must be very large. Of course, in actuality digestion has just barely begun at the esophagus, thus the empirically derived recognizability coefficients, as used here, also represent differential digestion between the esophageal and fecal stage. Regardless of assumptions made in conceptualizing such a process, it must still be concluded that any relationship used to predict dietary botanical composition from fecal composition must be highly variable and have significant bias that is dependent on the actual diet composition. Therefore, fecal analysis should only be used to determine the principal species constituents of the diet and to a certain extent, the relative importance value of species; for even if one only ranks by importance, esophageal and fecal data are not always closely related.

Table D1. An example of how known bias and variability can effect estimated dietary botantical composition through use of esophageal and fecal analysis.

Plant	Actual Diet Composition (%)	Coefficient of Indigestibility	Estimated[a)] Diet Composition (%)	Recognizability[b)] Low and High Positive and Negative Bias	Relative Contribution	Estimated Fecal Dietary Composition (%)	Estimated-Actual Range
Grass A	20	1.25	22.0	1.40	0.350	30.0	-1 to 10
Grass B	20	1.25	22.0	0.90	0.225	19.0	
Grass C	5	1.92	8.5	1.40	0.134	11.5	+2.5 to 6.5
Grass D	5	1.92	8.5	0.90	0.086	7.5	
Total Grass	50		61.0		0.795	68.0	+18
Forb A	20	0.83	14.5	1.10	0.183	15.5	-11.5 to -4.5
Forb B	20	0.83	14.5	0.60	0.100	8.5	
Forb C	5	1.12	5.0	1.10	0.062	5.0	-2 to 0
Forb D	5	1.12	5.0	0.60	0.034	3.0	
Total Forb	50		39		0.379	32.0	-18
TOTAL	100		100.0			100.0	

a) Coefficient of indigestibility is calculated from: grass estimate = 4.5 + 1.02 known, forb estimate = 1.97 + 0.73 known
b) See text for discussion of recognizability coefficients

3.3 Ocular Bite Counts

Ocular estimates of forage grazed date from 1952 when Hubbard (reported by Hubbard 1956) followed grazing cattle in Alberta, Canada. The technique was later refined by Reppert (1960), where observations for a 48-hour period consisted of following heifers as they freely grazed in 100 to 400 acre pastures. The estimates were done from a pickup truck using field glasses. Forage grazed was estimated in discrete mouthful units of 1/4, 1/2, 3/4, and 1, at a distance of 6 feet to 20 or 30 feet. A mouthful unit was recorded when the animal lowered its head to graze and ended when grazing stopped or the animal took a step forward. As may be realized, a partial mouthful unit can consist of several bites. Besides recording the plant species consumed, the plant part in terms of stems, leaves, and heads and other grazing habits were also recorded. However, the recording of estimates does not distinguish between different animals of the same species.

Ocular bite counts are perhaps the least expensive means by which dietary botanical composition may be estimated. Unlike other methods though, bite count data is observer dependent and requires a given level of expertise in the experimenter if one is to have confidence in the data. As a result, ocular bite count data can vary greatly between observers. In a study by Galt et al. (1969), ocular observations on species selected by rumen fistulated steers were compared to corresponding rumen fistula samples. There was considerable difference, up to 100%, in the bite count proportions of species when compared to rumen sample analyses.

Due to the discretized sample space, ocular bite count data can give at best only a qualitative range for estimating dietary botanical composition as demonstrated in the following example. Let S_i represent the i^{th} species in the diet being estimated. The proportion of the i^{th} species in a diet of n species can be represented by:

$$\frac{S_i}{\sum_{i=1}^{n} S_i} \qquad (1)$$

Due to a discretized sample space of 1/4 units, the S_i's are within a ($\pm$ 1/8) range at best. Thus, equation (1) is actually within the upper boundary of:

$$\frac{S_i + 1/8}{(\sum_{i=1}^{n} S_i)(1 + \sum_{i=1}^{n} e_i)} \qquad (2)$$

where e_i represents the error associated with a discrete estimate of the i^{th} species. If we assume that the distributionary e_i has a mean of zero, that is, the error is random or unbiased, then $\sum_j^n e_i=0$. When the estimated species comprise S_i of the diet, the range of S_i can be expressed by:

$$(S_i)\ \frac{1/8}{1} = \pm\ S_i \cdot 12.5\% \qquad (3)$$

By equation (3) there is a ($\pm$ S_i · 12.5%) range within which an ocular bite count estimate of dietary botanical composition would actually lie, assuming that there is no error associated with observations (standard error of the estimates = 0). Since Galt et al. (1969) showed there is considerable difference within observers for bite count data, the actual range is considerably larger than is expressed in equation (3). (However, bite counts can be corrected to size-per-bit using the methods of Kautz and Van Dyne (1978) so that end results are quantitative).

It is evident then that ocular bite count data can only provide at best, qualitative information about botanical composition of the diet of grazing animals.

The study by Sanders et al. (1980) used both bite counts and fecal analysis to determine cattle diets in Texas. Their major conclusion was that bite-counts and fecal-analysis methods give similar results for estimating major components of the animal's diet. Note here that the use of "major components" and not a more inclusive phrase. Given the above treatment of bias in bite-count methods, their conclusion about both methods being equal is somewhat disquieting.

3.4 Clipping

Dietary botanical composition of grazing animals may also be estimated indirectly by clipping plots before and after grazing to determine utilizations by the difference between the two clipping measurements (Van Dyne 1969). This method for determining range forage utilization by sheep was developed by Cassady (1941). The clipping technique consists of weighing clipped samples of forage species shortly before and again soon after the area was grazed. The differences in average weights of forage are assumed to be the amount of utilization by grazing animals.

The advantage of this method is that diet composition may be estimated without direct contact with the animal, which is also a prime disadvantage of this method. There are other disadvantages. The method is limited to an area where grazing can be completed in a short period of time so that plant dynamics (regrowth and shattering, etc.) do not significantly bias estimates of utilization. However, as the grazing period becomes shorter and total utilization is small, the less reliable is the utilization estimate. Furthermore, since differences in weight estimates are considered to be fully realized in the animals' diet, trampling, wind loss, error in estimating available herbage and other factors greatly undermine the reliability of the diet composition estimates derived from the clipping method. Thus, like the bite-count method, clipping should only be regarded as providing qualitative information of diet composition of grazing animals. Such a method can

however, give quantitative estimates of regrowth, shattering, trampling and other factors with proper controls; all of which need to be considered in any forage allocation decision process.

3.5 Direct Observation

Direct observations of tame and wild ungulates can establish forage species consumed and, in some instances, the amounts consumed. As with previously mentioned methods, there are advantages and disadvantages.

Use of direct observation of tame non-domestic herbivores is expensive only in terms of the observers time (Bjugstad et al. 1970). In the wild, some food choices can be quantified by habitat type. Wild animal observations can be designed to contrast site of grazing and time of grazing (both diurnal and seasonal), and large amounts of data can be collected in a relatively short time.

Tame animal observations allow minimal error of forage identification and allows observations at any time of the day. Wallmo and Neff (1970) say another benefit of tame animal observation is that the design of the experiment can be controlled by the experimenters and is not left to chance.

A major disadvantage of wild animal observation is that wild animals are difficult to approach closely enough to accurately identify the forage species (Wallmo et al. 1973, Bjugstad et al. 1970). As a consequence large, easily identified plants tend to be overestimated, while inconspicuous plants tend to be underestimated (Wallmo et al. 1973). Of course, sampling of wild animals must be done during daylight hours.

Disadvantages associated with tame animal observations include the often costly rearing, training and maintenance of experimental animals and the necessary period of adjustment after the animals have been placed in an unfamiliar environment (cage, fenced pasture, etc.). Also, the diets of tame animals may be supplemented with nutrients or concentrate. Veterinary care may also be a factor in the care of tame animals. Any of these items can cause tame animals to select forage different from the forage selected by wild herbivores of the same species.

The "costs" and the "benefits" of using direct observation of herbivores must be weighed prior to the selection of this method of ascertaining diet botanical composition.

3.6 Double Sampling

Since fecal analysis is poor as a quantitative means of estimating diet composition, a combination of fecal analysis and a few esophageally fistulated animals may be one feasible means of sampling. Such a double sampling technique could greatly reduce the cost of using fistulated animals only and could greatly reduce the variance of diet composition estimates over the use of fecal analysis methods exclusively.

In the double sampling technique, the analysis of the extrusa of the fistulated animal can be regarded as the "standard." The fecal analysis data would then be calibrated to the esophageal data in order to reach a "more accurate" estimate of dietary botanical composition. The calibration process can be accomplished by deriving a mathematical relationship, such as a regression model, between fecal data and esophageal data. Such a double sampling technique can be considered as an improvement if the variance of the estimates of diet composition are less than what the variance would have been if only fecal data was employed for the same cost.

For such a technique to be effective, a good mathematical model or regression model between fecal data and esophageal data is essential. Since the relationship is often very poor, such a model would have to be determined for each uniform site and its corresponding combination of herbivores on a seasonal basis. Through a partitioning of the data by site, combinations of herbivores, and season, a tractable relationship between esophageal and fecal data should follow.

The disadvantage of such a double sampling technique is the required use of fistulated animals. That requirement may not be feasible with wild herbivores, and even with some of the domestic herbivores. However, it is essential that precise data be made available on the dietary botanical composition of wild and domestic herbivores if sufficient use is to be made of the native grazinglands.

3.7 Summary of Methods

The methods used to determine the dietary botanical composition of selectively grazing herbivores comprise two types of techniques, direct and indirect measurement. The indirect measurement methods are bite counts, clipping and fecal analysis. The use of fistulated animals is perhaps the best direct method since it allows for replicate data within animals. Observation of wild and tame animals is another direct method. The fecal analysis method is capable of partitioning data within samples though this is rarely done.

The direct measurements are preferable due to the information that is available through such methods that aren't available with the indirect methods. The chief benefit from using direct methods is realized when replicates of data among animals is gathered, since only with replicates among animals can the error associated with the technique of analysis be bounded or estimated. Without a knowledge of the error within measurements, the data must be accepted on what amounts to blind faith. The degree of blind faith held for data in the literature is clearly apparent when researchers report diet composition to the 0.1% and even 0.01%, as if they could ascertain such precise differences in the data. Even more remarkable is that regardless of the degree of precision reported, rarely if ever are standard deviations reported. Such simple statistics are essential for a thorough understanding of the precision of the data on diet botanical composition.

Indirect methods have greater disadvantages than even the unknown error of measurement associated with them. Such methods as ocular bite counts and fecal analysis can only distinguish the variability among herbivores. Clipping, the least precise method, cannot distinguish between herbivore

species and the data derived thereby is significantly complicated by plant dynamics, trampling and other factors. Such complications can result in very inaccurate estimates of forage utilization and diet composition.

Becuase of the problems associated with diet composition analysis methods, the sources of variation and error of at least fecal and esophageal data need to be determined and estimated through a badly needed study. Briefly, such a study would be comprised of an analysis of both diet composition analysis methods of known diets fed to herbivores and the analysis of only masticated samples of known mixtures as well. The degree of accuracy and precision of the two techniques could be determined as a result of such a study. Furthermore, it may be possible to improve on the accuracy of the techniques by determining digestibility coefficients as a result of the differences between digested and masticated samples. The known bias of the data due to differential digestion could then be quantitatively expressed and accounted for, as well as the variability of differential recognizability on the part of technicians. The principal cost to such a study would be the laboratory fees, data sampling cost, and subsequent statistical analysis and reporting. Until such a study is undertaken, the obvious problems with the diet composition analysis methods can only be discussed and not quantitatively taken into account.

4.0 PHOTOSYNTHETIC PATHWAYS

In the mid-1960s, plant physiologists studying the mechanism of photosynthesis found a photosynthetic pathway in some species of the Graminae and in corn (*Zea mays*) that produced 4-carbon intermediate compounds (Kortschalk et al. 1965, Hatch and Slack 1966, 1967a, 1967b). This pathway differed from the previously understood pathway which produced a 3-carbon intermediate compound (Calvin and Bassham 1962). Subsequent studies showed that the 4-carbon pathway or C_4 pathway was linked to specific characteristics of morphology and ecology of the plant species in which it occurred (as well as to the physiology of the plant).

A third photosynthetic pathway different from the 3-carbon compound or C_3 pathway has also been identified. First discovered in succulent plants of the family Crassulaceae native to desert climates, and using intermediate metabolic acids, it is named Crassulacean Acid Metabolism or CAM (Ranson and Thomas 1960).

This section briefly discusses these pathways, explains the ecological consequences of these pathways (insofar as they are known), and explains their importance in the study of dietary botanical composition of large herbivores.

4.1 The C_3 and C_4 Photosynthetic Pathways

Both the C_3 and C_4 pathways produce end products of six carbon sugars which are used in the metabolic processes that release energy. These end products may also be incorporated into more complex compounds such as starches, celluloses and hemicelluloses.

The C_3 pathway requires inorganic carbon dioxide and the 5-carbon sugar ribulose-1,5-diphosphate. In the presence of the enzyme ribulosediphosphate carboxylase, CO_2 and the 5-carbon sugar form two molecules of the 3-carbon acid, phosphoglyceric acid.

The C_4 photosynthetic pathway uses carbon dioxide diffused through stomatal openings into the mesophyll cells. The CO_2 then reacts with phosphoenolpyruvate to produce oxaloacetic acid which in turn forms the 4-carbon compounds of either malic acid or aspartic acid (the latter, an amino acid). The enzyme which catalyzes this reaction is phosphoenolpyruvate carboxylase. Once the 4-carbon intermediates are formed, they pass into bundle sheath cells and are decarboxylated. The liberated CO_2 formed thereby is then fixed into phosphoglyceric acid, the same product of the C_3 pathway.

4.2 Crassulacean Acid Metabolism (CAM)

In desert environments, some succulents subject to drought, cool nights and hot days, fix carbon dioxide by the phosphoenolpyruvate carboxylase reaction and store it as malic acid. The distinguishing feature here is that this reaction takes place at night. During the day, the malic acid is decarboxylated and the freed CO_2 is incorporated into phosphoglyceric acid by the ribulosediphosphate carboxylate reaction. These plants are termed CAM plants (Ranson and Thomas 1960).

Under conditions of ample and relatively cool days and warm nights, plants with the CAM photosynthetic pathway behave much as do C_3 plants and fix CO_2 via the C_3 photosynthetic pathway (Osmond et al. 1973).

4.3 Ecological Significance of Photosynthetic Pathways

The ecological significance of the three photosynthetic pathways is dependent on the morphology and physiology of the plants in which they occur. Plants which have the C_4 photosynthetic pathway have chloroplasts in the leaves concentrated in bundle sheaths around the veins of the leaf. This distinctive morphology, referred to as the Kranz syndrome (Laetch 1974), apparently enables the plant to incorporate a substantially greater amount of CO_2 into the leaf prior to the formation of phosphoglyceric acid (Chollet and Orgren 1975). This feature is probably an adaptive advantage for C_4 plants, giving them higher rates of photosynthesis (and therefore photosynthate production) at lower ambient CO_2 concentrations than C_3 plants.

Black (1971), Chollet and Orgren (1975) have detailed other important differences between C_3 and C_4 plants. Plants with the C_4 pathway do not reach light saturation levels even in full (100%) sunlight while C_3 plants are light saturated at one-fourth to one-third full sunlight levels. The point at which the photosynthetic process balances the respiration process so that net CO_2 uptake is zero and net O_2 production is zero is called the compensation point. Plants of the C_3 variety reach the compensation point at 30 to 70 parts per million (ppm) of ambient CO_2 while C_4 plants reach the compensation point at levels of 0 to 10 ppm CO_2.

On the basis of milligrams of CO_2 fixed per square decimeter of leaf area per hour, C_3 plants are less productive. They have rates of between 15 to 40 mg CO_2 $dm^{-2}hr^{-1}$ while C_4 plants have a range of 40 to 80 mg CO_2 $dm^{-2}hr^{-1}$. Photorespiration is absent or very low in C_4 plants while C_3 plants have high rates of CO_2 generation in light. This is significant since CO_2 generation comes from the respiration of photosynthetic products. Three-carbon plants, therefore, must incorporate more CO_2 than C_4 plants just for maintenance.

Two more points are important. On the basis of production of dry matter produced per hectare per year, C_3 plants in general produce about 22 tons while C_4 plants produce 39 tons. Maximum photosynthesis in C_3 plants occurs at about 20-25°C while C_4 Plants have an optimal temperature range of between 30-35°C.

The features of temperature range for maximum photosynthesis and the known responses of C_3 and C_4 plants to light intensity give a qualitative way of determining the photosynthetic pathway of a particular plant species from phenological development. If a plant grows, produces inflorescences and sets fruit during times of the year when temperatures are relatively low (the cool-season) and when light intensities are reduced, it is probably a C_3 plant and is commonly referred to as a cool-season plant. If however, maximum phenological development occurs during the warm season when temperatures and light intensities are high during the day, the species is probably a C_4 plant (Waller and Lewis 1979).

In short, C_4 or warm-season plants are at an advantage when photosynthesis is limited by CO_2 concentration, when light intensities are high, when high temperatures prevail and, because of their relatively low transpiration rates compared to C_3 plants, when water is not readily available (Bjorkman 1973).

Krebs (1978) has summarized the features of the CAM pathway. These plants have very low transpiration rates and maximum rates of photosynthesis of 1 to 4 mg $dm^{-2}hr^{-1}$ of CO_2 fixed. CAM plants have compensation points of about 5 ppm CO_2 in the atmosphere during the night and up to 200 ppm ambient CO_2 concentration during the day. Photorespiration is probably present but the level is difficult to detect experimentally. The optimum temperature for growth for CAM plants and hence for photosynthesis is about 35°C. Dry matter production per hectare per year is extremely variable as is light saturation of photosynthesis. The latter, though, is probably well below full sunlight.

From the above, it would appear that C_4 plants are superior in every respect when compared to C_3 and CAM pathway plants (Black 1971). However, C_4 plants do have one known disadvantage. That is, up to about 30°C, C_3 plants incorporate more CO_2 per light energy quanta absorbed than do C_4 plants (Ehleringer 1978). Further, some C_3 species do exist which have maximum photosynthesis rates on a leaf area basis equal to or exceeding the highest known C_4 species rates (Mooney et al. 1976).

As Ehleringer (1978) points out, C_4 plants are not ubiquitous which suggests C_4 photosynthesis is not advantageous in every environment. He further suggests that the C_4 photosynthetic pathway might even be disadvantageous in some regions. Teeri and Stowe (1976) have shown that C_3 plants predominate in cool-temperature regions while C_4 plants are most abundant in subtropical and desert areas of the world.

4.4 Photosynthetic Pathways and Dietary Botanical Composition of Large Herbivores

Response of large herbivores to the presence or absence of a particular photosynthetic pathway is largely a matter of preference and the forage intake requirements needed for physiological maintenance and growth. Forage intake requirements of large herbivores and factors affecting diet selection are dealt with in Chapters C and E, respectively.

Still, photosynthetic pathways present in forage plants can affect herbivore species. Caswell et al. (1973) have proposed an hypothesis which states that generally C_4 plants are poorer food sources than are C_3 plants. They contend that this hypothesis is supported in part by the fact that herbivores tend to avoid feeding on C_4 species. Krebs (1978) states that animals feeding on C_4 species have lower survival rates and lower fecundity. They are also avoided in laboratory preference tests. The above studies, however, deal primarily with insects rather than with the large herbivores which are the subject of this review.

If the above statements and hypothesis are true for large grazing animals, then one would expect consistantly less warm-season plant components in the animal diets. This prediction is discussed in succeeding sections.

4.4.1 Assignment of Photosynthetic Pathways to Diet Components

There is a large body of literature which designates plant species as warm-season or cool-season. Papers in this literature consist of compilations of plants according to photosynthetic pathway (Waller and Lewis 1979, Downton 1975), papers which discuss photosynthesis and cite various plant species as examples of plants having a particular pathway (Black 1971) and papers which label a plant as having C_3 or C_4 pathways without giving a source or the criteria for such a designation (Troughton et al. 1974).

We have compiled a list of plants, both monocots and dicots, broken down according to plant species and the stated photosynthetic pathway (Skiles and Van Dyne 1981). The list consists of 1585 entries taken from 21 sources (see Section 4.4.3). From this list we have assigned photosynthetic pathways to plants that appear as components of large herbivores' diets. The pathway was assigned when one or more of the sources so designated a plant species' pathway. For grasses, there were few plants that appeared in the diet for which no pathway could be assigned. Fewer forbs have apparently been studied to ascertain photosynthetic pathways as only about 60% of forbs appearing as large herbivore diet components could be assigned a pathway. Shrubs and browse were rarely assigned a pathway as very few references designated pathways for them.

In some instances, two or more references gave conflicting photosynthetic pathway assignments. That problem is addressed next.

4.4.2 Provisional Assignment of Photosynthetic Pathway to Diet Components

Those authors who use the designation of C_3 or C_4 plants or cool-season or warm-season plants in their studies but do not cite an authority for such designations present a problem when the objective is to compile species lists according to photosynthetic pathway. Warnes and Newell (1969) and Conard and Youngman (1965) are papers that report on studies which use as an hypothesis the differences between C_3 and C_4 plant responses to environmental changes that are due to the mechanisms of the two photosynthetic pathways. Yet, the workers do not elucidate their criteria for designating one plant species as C_3 and another as C_4.

The above two cited papers consider less than ten plant species in each. A greater problem are those papers that present extensive plant lists broken down according to photosynthetic pathway but again do not cite the criteria or authorities used for those designations. A case in point is the paper by Sims et al. (1978). The problem is exascerbated when the compilation contains errors. For example, they list seven species of Opuntia as warm-season plants, but Troughton et al. (1974) claim Optuntia polyacantha is a CAM plant. (The Opuntia sp. designation in the Sims et al. 1978 paper may be in part due to the species' phenological development, during the warm-season). The authors give no clue, however, as to their criteria for the warm-season designation. Sims et al. (1978) list Sporobolus cryptandrus as a C_3 plant while four sources (Kautz and Van Dyne 1978, Downton 1975, Waller and Lewis 1979, Smith and Brown 1973) consider that species a warm-season plant.

The errors in the above paper represent incorrect designation by the authors. Type-setters and printers also make errors. Waller and Lewis (1979) is such an example. The most noticeable error in that paper is the designation of corn (Zea mays) as a C_3 plant. The error here was made at the printer (Lewis personal communication). However, one of the references consulted does assign Zea mays a C_3 pathway (Smith and Brown 1973). It is unknown whether this latter designation is an author or printer error.

A further complication are those dietary botanical studies which report dietary components to the genus level only. That is not a problem when it is known that all the species within a genus possess one particular photosynthetic pathway. Genera do exist, however, which include species that are C_3 and species that are C_4. Examples include Artemisia sp., Atriplex sp., Flaveria sp., Panicum sp. and Senecio sp. (There are also genera (Mollugo) that exist which possess species that are apparently evolutionary intermediates between C_3 and C_4 metabolism (Kennedy et al. 1980). This is a further complication.) Therefore, in this review in instances where dietary components were reported only as to the genus and where photosynthetic pathways of both C_3 and C_4 appear in that genus, no photosynthetic pathway assignment was made. In instances where the references consulted disagreed as to pathway, no assignment was made. Where a number of species in a genus were listed as, say C_3, and that genus was not anywhere listed as C_4, a new genus species name encountered in the dietary composition work was assigned a provisional photosynthetic pathway of C_3. Finally, when a genus species name occurred once and only once in our plant list and a species was reported as a dietary component that had the same genus name but was a different species, the species was provisionally assigned the same pathway as the species on our list. Provisional assignment of photosynthetic pathway is denoted in the botanical composition of diet tables with a "+".

4.4.3 Sources Used for Photosynthetic Pathway Assignment

The sources used for the compilation of plant species and their photosynthetic pathways are cited in this section. The complete reference is given in the Literature Cited section. The sources used were: Black (1971), Brown (1978), Conard and Youngman (1965), Downton et al. (1969), Downton (1975), Ehleringer (1978), Gerwick et al. (1980), Gurevitch (1980), Kautz and Van Dyne (1978), Lerman et al. (1974), Medina and Troughton (1974), Sims et al. (1978), Smith (1976), Smith and Brown (1973), Smith and Turner (1975), Teeri and Stowe (1976), Troughton and Card (1975), Troughton et al. (1974), Waller and Lewis (1979), Warnes and Newell (1969) and Williams and Markley (1973).

5.0 UNPUBLISHED BUREAU OF LAND MANAGEMENT DIET DATA

The Denver Service Center of the Bureau of Land Management in 1977 requested from various State Directors and district offices in the western United States information concerning dietary botanical composition on wild horses and burros as well as other large herbivores on public lands. They were collecting information on the fecal analysis studies that had been done in various states and districts. Mr. Melt Frei compiled this information and provided the original data to us for our consideration. The information we have summarized here we believe is relatively complete up through early or middle 1979.

Table D2 provides a summary of the data provided by the districts and states (i.e., those that had such information at the time) and which have been compiled and summarized herein (see Appendix III).

No detailed information was provided to us as to the methodology of data collection, interpretation, or its accuracy or precision. Most, if not all of the analyses of botanical composition on these fecal samples was made by micro-histological analyses through a commercial food composition analysis laboratory. No data are available as to the number of sampling units (pellet groups, fecal collections, etc.) that went into each individual data point. In some cases the year and the season of collection were not well defined. In other cases it was difficult to decipher what plants were determined in the analysis.

We have summarized the data, to the best of our ability, according to animal species (cattle, horse, sheep, deer, elk, pronghorn antelope, burro, or other), year, season, months, and plant species or group. We have presented plants according to Latin names. In some cases original data were defined by Latin names and in other cases only common names are given. We have assigned what we feel is the most probable Latin name for a given common name for plants in that region. We have also assigned the SCS plant codes (USDA Soil Conservation Service 1971) based on the "National List of Scientific Plant Names". We have used both the original 1971 list and the updated 1978 listing of such names. Given the most probable Latin name of the species or group, we have assigned the most probable growth-season response for the plants, i.e., C_3 or C_4 referring respectively to what are usually termed cool-season or warm-season plants. When the "+" sign is used with the C_3 or C_4 designation designation it means that we are assigning a provisional classification (see Appendix Tables IIII through III10).

We have subdivided the data into two groupings in our summarization. First we take those plant species or groups which represent 5% or more in the diets of the herbivores for which data are reported. We report separately simply the listing of Latin names of the species or group for those plants which are less than 5% in the diet. Thus, the tables in Appendix III can be referred to in pairs, the first always being the summary for those plant species or groups with 5% or more in the diets and the second those for less than 5%. We chose this "breaking point" of 5% because we feel that the precision of the data at best is no greater than estimating diet ccomposition to the nearest 5%.

Table D2. A summary of the kind and extent of unpublished Bureau of Land Management data on dietary botanical composition of large herbivores as derived from fecal analysis.

DISTRICT	STATE	SUMMARIZED	CATTLE	HORSE	SHEEP	DEER	ELK	ANTELOPE	BURRO	OTHER	YEAR	SEASON	MONTHS	NOTES
Safford	Arizona		X			X					1976	Summer		
Phoenix	Arizona		X			X					1976	Summer		
Bakersfield	California								X		1974		August	
Cedarville	California	X	X	X	X	X		X			1976		July-November	
		X		X		X		X			1977		January-March	
		X	X	X	X	X		X			1977		April	
		X		X				X			1977		December	
Susanville	California		X	X	X	X		X			1976		July-December	District summaries only by group
Salmon	Idaho		X	X		X		X			?		?	Illedgible
Boise	Idaho		X	X	X	X		X			1976		June-August	
Lewiston	Montana			X							1974	Summer	October	
				X		X					1975		July, October, January	
				X		X					1976		January, April	
Farmington	New Mexico	X	X	X		X					1977		January, May	
Socorro	New Mexico	X	X	X		X					1976	Summer, Fall		
		X	X	X		X					1977	Spring		
Elko	Nevada	X	X	X		X					1976	Yearlong		Nawa
		X	X	X		X					1977	Yearlong		Nawa
Ely	Nevada	X	X	X	X			X			1975	Winter, Summer, Fall		
		X	X	X	X						1976	Winter, Summer, Fall		
Winnemucca	Nevada	X	X	X				X			1976		November	
		X	X	X		X		X			1977	Spring		
Salt Lake City	Utah	X	X	X		X					?	?	?	
		X	X			X	X	X			1976	Fall & Winter		
Cedar City	Utah	X	X								1977		February, April, May	
		X				X					1977		May	
		X		X							?	Summer & Spring		
		X		X		X	X				?	?	?	
		X	X	X		X	X	X		X	1978			
Rawlins	Wyoming	X	X	X	X	X	X	X			1976			
		X	X		X		X	X			1977			
Rock Springs	Wyoming	X	X	X	X	X	X	X		X	1974 - 1976	Spring & Summer Fall & Winter		Elk data suspect Not all animals represented in each season

We have averaged the data within seasons and animal groups for given localities by two different methods. First we derived an average from the original data points. For example, in one instance there might have been 20 individual samples which came from 4 sub-areas within the district or zone. We consider these as the "weighted" mean or average. These 20 samples may have been taken in 4 different subs-zones. A second average we give is the simple arithmetic average of the 4 zone means. Thus in the tables in Appendix III, for plant species representing 5% or more in the diets, two sets of means are provided.

The data in Appendix Table III are presented with up to four significant figures. This is simply a calculation artifact. We do not imply that the data are that precise. In effect, the values should be rounded to the nearest whole percent at best.

Considerable caution should be exercised when interpreting dietary composition data from fecal analyses methods. It has been shown in several studies that there is a bias in estimates of percentage composition by weight of plants in diets based on fecal analysis. This is because of differential digestibility and differential recognizability of the plants in the fecal material as we have discussed in Section 3. Generally, one can expect a positive bias in the percentage composition for shrubs and a negative bias in the percentage composition for forbs.

We present the data in their present state of aggregation and analyses primarily for their reference value. Because the sampling and collection design are not well specified in most cases, it is difficult to make further analyses and interpretations at this stage. However, with considerable further effort in analysis, these data could yield additional needed information concerning dietary botanical composition of large herbivores on public lands. Resource management agencies should promote and support further collection, analysis, reporting, and interpretation of such information according to a reasoned, thorough, and uniform design.

6.0 DIETARY BOTANICAL COMPOSITION OF LARGE HERBIVORES

The information and data presented in this section is a summary of the dietary botanical composition of large herbivores based on information extracted from the open scientific literature. Some 137 references were used in the compilation. The information from each of those references is tabulated according to animal in Appendix IV which consists of 20 tables. The large herbivores considered were cattle, sheep, bison, bighorn sheep, pronghorn antelope, mule deer, whitetailed deer, elk, horses, and feral burros.

Throughout this section reference will be made to Appendix IV which contains two tables for each of the 10 herbivores listed above. Odd numbered tables refer to diet component of 5% or greater while even numbered tables refer to diet components of less than 5%.

The tables were compiled as each reference was found in the literature. A number was assigned to each of those references. For brevity, the following discussion uses reference numbers rather than the full citation. Figure D1 shows the approximate geographical location where each of the dietary botanical composition studies were done.

The tables show across the top reference numbers then any specific season or treatment or stocking regime which was a study variable and important in interpreting results. Also shown is the method whereby the botanical composition of the diet was determined. These are abbreviated as follows: BC, bite count; CP, clipping or plucking; ES, esophageal analysis; FA, fecal analysis, HS, hunting season; ME, microhistological examination; OE, occular estimation or observation; RO, random observation; RA, rumen or stomach analysis;l and WE, weight estimate.

The left side of the table lists an SCS plant code, the Latin name of the plant species, and the photosynthetic pathway of the plant if known. Table entries are percentages of that plant in the diet reported by that reference.

6.1 Domestic Herbivores

The primary economic concern for the grazingland resource manager is use by domestic herbivores of the range resource. The domestic animals considered in this subsection are cattle and sheep.

6.1.1 Cattle

Appendix Tables IV1 and IV2 deal with the information extracted from the literature for cattle. Some 49 sources of cattle diet botanical composition were used to produce the 88 entries in Appendix Table IV1. The various states in which those studies were carried out are Arizona, California, Colorado, Georgia, Idaho, Montana, New Mexico, Nevada, Oregon, Texas, Utah, and Washington. The studies were carried out in all seasons and used fertilized and unfertilized pastures, light and heavy grazing regimes, etc.

The highest single entry for a grass species was 59% Sporobolus cryptandrus in reference number 17 for May through October on an "old field" pasture. Agropyron sp. made up 54% of cattle diets in the study reported by

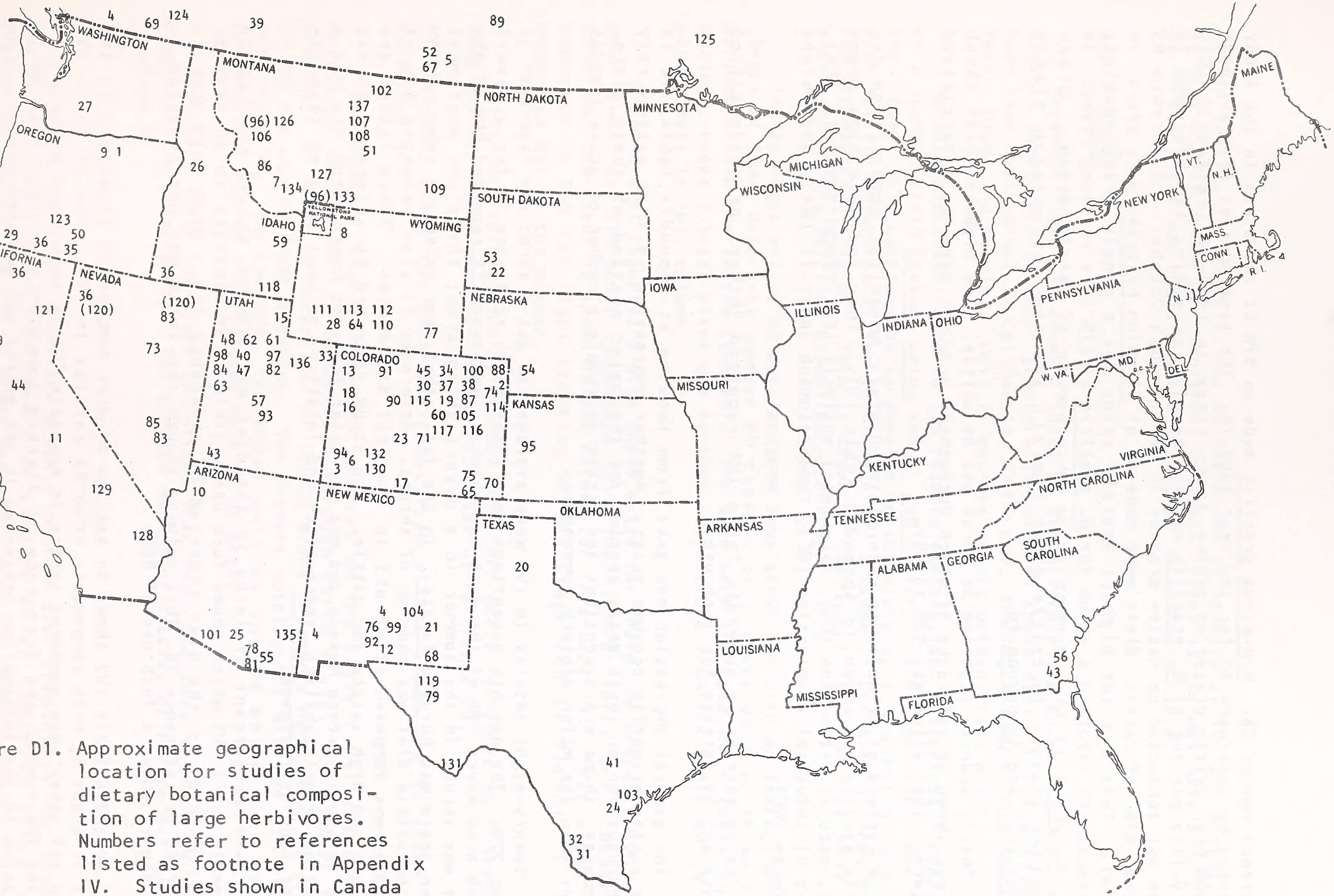

Figure D1. Approximate geographical location for studies of dietary botanical composition of large herbivores. Numbers refer to references listed as footnote in Appendix IV. Studies shown in Canada are according to approximate longitude only. Parentheses refer to more than one location used in a study.

reference number 28. Bouteloua gracilis made up 57% of the diets in the study reported by reference 60 for the year 1969-70. The same species of grass made up 50% when cattle grazed on native grass range in 1967-68 (reference 70). Fifty-five percent of B. gracilis was in the diet according to reference 75 which was conducted on native grasses in May through October. Reference 85 showed 63% of cattle diets were made up of Sitanion hystrix, a C_3 grass, in winter. This was the highest overall value for a single grass species. Reference 103 reported a value for B. gracilis of 61% in a yearlong study. In all, B. gracilis is a common grass in a number of cattle diets. Other important grasses in cattle diets overall are the cool-season plants Bromus sp. and Agropyron sp.

Thirty sources reported no shrub use by cattle. The highest total shrub use was shown in reference 44 which documented a study done on a fertilized pasture. That value was 49% shrubs.

A variety of methods for determining dietary botanical composition for cattle studies are shown in Appendix Table IV1. They included bite count (BC), occular estimation (OE), esophogeal analysis (EA), fecal analysis (FA), micro-histological examination (ME), rumen/stomach analysis (RA), and weight estimate (WE).

Seven entries in Appendix Table IV1 reported "other" or unidentified plants and 39 entries for forb use.

The general impression one gets from looking at Appendix Table IV1 is that cattle primarily consume grass. Another impression is that cattle rely on perhaps two or three grass species for the major portion of their diets. Of course, there are exceptions and cattle do sample a number of grass species other than the major dietary components.

Twenty-eight entries in IV1 were averaged to get a shrub use "average" of about 27%. The notable exceptions were reported by reference 73 for a desert shrub area where 74% of the diet was shrubs. Reference 83 reported 80% of the diet was shrubs in the summer in a desert shrub area; the plant used most often there was Eurotia lanata. In the fall, that same reference reported 95% of the cattle diet was made up of shrubs. Reference 83 also reported 83% of the diet was composed of shrubs in the fall and winter. These latter are unusual and high totals for cattle. The study reported by reference 83 was done in south-eastern Nevada and one may infer that the heavy shrub use was a function of palatability, seasonality and locality, perhaps more so than the other studies reviewed.

Average percent of forbs in the diet was 27% for the 57 entries in Appendix Table IV1 which shows forb use. (This is in contrast to an average grass percent in the diet reported by reference 71). High forb use is reported by reference 78. That column, though the total was not reported in the study, shows a forb use of 86%.

Appendix Table IV2 shows an average of diet components (species) in the diet of about 8, with components from 64 entries in IV1. Use of Table IV2 (and all other even numbered tables in Appendix IV) is restricted primarily to noting the number and frequency of dietary components of less than 5% in relation to the information presented in the paired odd numbered tables. Low

totals in IV1, for example, may be explained by looking at IV2 and noting that several highly preferred plants are present. These latter may have been close to 5% and their sum explain the discrepency in the main table.

6.1.2 Sheep

Appendix Table IV3 shows a total of 28 reference and 60 entries for sheep dietary components of 5% or greater. Studies on sheep diets are reported to have been carried out in California, Colorado, Idaho, Montana, New Mexico, Texas, Utah, and Wyoming. Only 11 entries report unidentified plants.

Special characters used in IV3 require explanation. Reference 8 reported on a study wherein Festuca ovina and F. rubina were indistinguishable one from the other. This combination is denoted in the table by a bracket preceeding each entry. Reference 49 for forbs reported a range in the diet of from 2% to 10% for Medicago hispida. This is shown in the table as 2- on one halfline above and 10 one halfline below the main line.

Twenty-eight out of 68 entries show some shrub use with an average use of shrubs of 33%. Reference number 80 reports on a study done at three time periods within one season (summer). The data were averaged over these three periods, hence a total plant use of 100% is possible from the addition of the percentages in this column.

Reference 81 reported a high shrub usage for sheep, an entry of 83%. The next lowest was 75% under reference 47. The highest shrub use (though no total was reported) is shown in the column for reference 63. That usage was reported as 99% for light stocking of the range and treatment II (see reference 63) in the winter.

Thirty-one entries out of 88 show some forb use at or above 5%. Average forb use for those entries is 32% (exclusive of reference 80).

Highest entry for forb use comes from winter study and is shown for reference 84.

The highest single entry for grasses in the table (IV3) comes from reference number 58 for an October through March study. Reference 63, treatment I, shows a heavy use of the C_3 grass Oryzopsis hymenoides; a value of 55% for winter light stocking. The highest total grass use was 95% under reference 77. On average, for those entries in IV3 which show grass consumption, 46% of the diet was made up of grass.

Appendix Table IV4 shows 38 entries that recorded less than 5% of diet components in sheep diets. The average number of species of forage per entry is about 9.

6.2 Bison

Appendix Table IV5 shows the greater than 5% diet components for bison. Two references (38 and 88) report on studies which indicate bison use significant amounts of the C_4 plant Bouteloua gracilis under various stocking regimes and during the summer and fall months. However, under

references 89 and 125, Carex sp. (a C_3 plant) is the single largest diet component in summer and fall. References 89 and 125 refer to studies done in Canada while references 38 and 88 are for studies conducted in northeastern Colorado. The use of the two different plant species by bison is almost surely a function of what plant grows most abundantly on which study area and not animal preference *per se*. Based only on the four references shown in IV5, bison rarely use forbs or shrubs.

Appendix Table IV6 shows diet components for bison that are less than 5%. The average number of species per entry in Appendix Table IV5 is 11, though one instance is shown of some 30 species in the diet, each less than 5% of the total.

6.3 Bighorn Sheep

Our compilation for bighorn sheep came from 7 sources and produced 17 entries in Appendix Table IV7. Bighorn sheep diets are made up in large part of grass though forb use can be high depending upon the season. Shrubs are also used heavily (reference 6, 130), but this may be a terrain or site location effect.

Appendix Table IV8 for less than 5% of the diet components has an average number of plants per entry of 17.

6.4 Pronghorn Antelope

Appendix Table IV9 shows the compilation for pronghorn antelope diets with components of 5% or greater. There are 40 references and 85 entries. The studies from which these data were gathered were conducted in Alberta and Saskatchewan, Canada, California, Colorado, Idaho, Kansas, Montana, Nebraska, Nevada, Oregon, South Dakota, Texas and Wyoming.

Of interest is the use by pronghorn of cactus wheat and cultivated plants. In some instances, cactus (Opuntia sp.) is a significant portion of antelope diets.

Few grass species are used by pronghorn antelope as shown by the number and amounts of grass species in IV9; there are only six evenly divided between C_3 and C_4 species. The highest entry occurs under reference 34 for a total of 52% grass in the diet on a heavily grazed pasture. Forty-four percent usage occurred in the same study but under the light grazing regime. It is not possible to infer whether C_3 or C_4 grasses predominate in the diet from the data in IV9. Average grass use for entries that reported grass use was 15%.

The highest entry in the total forb forage class was 95% for June and July under reference 48. That study employed a variety of diet composition determination methodologies including random observation, rumen extrusa analysis and (occular) observation. Reference 107 shows a forb usage of 85%; reference 96 shows 80% forb usage. Sixty-eight of 85 entries for forb use by pronghorn antelope are shown in Appendix Table IV9. The average of these was 35%. Streptanthus cordatus was consumed as reported by two studies but there

does not appear to be any one or two mainly used forbs. Salsola kali and Eriogonum effusum were used minimally by antelope as shown in Appendix Table IV9.

The highest shrub use by pronghorn antelope occurred on a sagebrush-steppe rangeland during the winter. That use was 100% shrubs in the diet (reference 107). Chrysothamnus vicidiflorus was reported as being used by antelope in only one study, but it was used on all four study variations. It is unknown what the herbage composition of the range was or why this C_4 plant was (apparently) actively sought by the antelope.

There are 72 out of 85 entries in Appendix Table IV9 which report shrub use. In these 72, the average shrub use was 68% shrubs in the diet.

Appendix Table IV10 shows diet components for pronghorn antelope of less than 5%. Of note is one entry for 110 plant species which were in the diet but in small amounts. That number is contrasted with several entries of only one plant species. The average number of diet components of less than 5% for pronghorn antelope is about 15.

6.5 Deer

6.5.1 Whitetailed Deer

Appendix Table IV13 shows 5 references with 11 entries. The geographical range of diet studies done on whitetailed deer includes Arizona, Montana, and Texas.

Whitetailed deer do not appear to eat much grass. The overall impression is that they consume more shrubs than any other forage class. Five percent or greater components include at times Agave sp. and Opuntia sp. A predominant photosynthetic pathway for the plant species which whitetailed deer utilize most is difficult to determine.

The Appendix Table IV14 shows that whitetailed deer are not all eclectic in their diets. The average number of diet components less than 5% is 11 though some entries are as high as 76 plant species.

6.5.2 Mule Deer

Appendix Table IV11 shows diet components greater than or equal to 5%. Grasses are used very little but when consumed at all they are mostly C_3 species. These animals are consumers or samplers of a wide variety of vegetation as our compilation showed an average of 13 diet components per entry with less than 5% usage (Appendix Table IV12).

Mule deer even consume at times Pinus sp., Salix sp., and Juniperus sp. at or above the 5% level.

6.6 Elk

There are 10 references and 17 entries for the elk Appendix Table IV15). It will be noted that C_3 grasses predominate in the diet where they are present, even in the warm part of the year.

Heavy winter shrub use was reported for elk in references 89 and 132. Reference 132 reported a concommitant heavy spring and summer use of grasses.

Appendix Table IV16 shows the diet components for elk which were less than 5% of the diet. The average number per entry in IV15 and IV16 is 12, with the highest being 22 and the lowest being 3.

6.7 Horses

Appendix Table IV17 shows diet components equal to or greater than 5% for horses. The table shows six references and eight entries. The studies were done in Alberta, Canada, New Mexico, and Colorado in the combined seasons of spring-summer and fall-winter.

Of the eight entries in the horse table, only reference 4 reported any use of shrubs and forbs above 5%. Reference 67 reported unidentifiable plants used 18% and 27% in spring-summer and fall-winter. It is unknown if any of these percentages were in whole or in part for forbs and/or shrubs.

Reference 4 reported shrubs used by horses were Prosopsis juliflora and Atriplex sp. Salsola kali was used up to 32% in the fall-winter according to reference 4.

The highest use of grass shown in Appendix Table IV17 was 54% of the C_3 grass Stipa sp. in the summer and was reported by source 17. There are no entries of 40% grasses in horse diets but several in the 30% to 39% range. The 30% entries include Carex sp. and Stipa sp. Sporobolus sp. was used to 23% in spring-summer according to reference 4. Carex sp. and Stipa sp. were used in some instances to the 20% to 29% level.

According to the tabular information, a genus common to the diet of horses is Carex sp. as is the genus Agropyron sp. Koeleria cristata also appeared in the horse diets.

From these data, horses appear to be consumers of grass except in southern New Mexico in the locale of reference 4. There, the use of shrubs and forbs indicate location specific consumption of plants. Also, it should be noted that only reference 4, of the six references, reported consumption of C_4 grasses. These were Leptochloa dubia and Sporobolus sp. Based only on reference 4, when C_4 grasses are used it appears that forbs and shrubs are added to the diet.

Appendix Table IV18 reports diet components for horses of less than 5% for entries in Appendix Table IV18. The average number of less than 5% plants per entry is about 8. Some of the plants listed in IV18 are grasses but there are a number of forbs and shrubs. Among these are Pinus sp., Artemisia sp., and Quercus sp. It is unknown whether these traces were taken by the animals

because the plants were novel and attractive to the animal, or whether the trace amounts were shoot or fruit material and therefore tender and moist, or whether they were selected because nothing else was available or palatable. Given the error in sampling methods discussed earlier some of these items may in fact be sample contamination or not present at all.

6.8 Feral Burros

There are three references reported for burros in Appendix Table IV19. These references (10, 128, and 129) report on studies carried out in Arizona and California. There are eight entries in the table for feral burros. The seasons for which data are reported are annual, spring, summer, fall, and winter, and spring and fall. One source reported data for the single month of March. Reference 128 reported 76% and 78% for total shrubs in the diet for summer and fall respectively. The highest percentage shown in Appendix Table IV19 is 49% of Plantago insularis measured during the spring by the work reported in reference 128. Six species of grasses are listed as being in burro diets over all three studies, two forbs and eight shrub species.

From the data shown in Appendix Table IV19 it is difficult to judge major dietary components for burros. They apparently eat site-specific and location-specific plants.

Appendix Table IV20 shows the plants in the diets of burros of less than 5% per each entry in Appendix Table IV19. The average number of plants for each entry is about 19. This shows that burros sample many plants but only a few up to or above the 5% level.

Table D3 is a summary of the number of references, number of entries and the geographical range of studies of diet botanical composition of large herbivores. Table D4 shows the number of species according to forage class found in the diets of large herbivores from our compilation. Also shown is the number of C_3 or C_4 plants we were able to identify using our plant list.

Table D3. Summary of number of references, number of entries, and geographical range of studies of diet botanical composition of large herbivores.

Herbivore	Number of References	Number of Entries	Seasons	Geographical Range[a/]
Cattle	49	88	all seasons[b/] treatment[c/]	AZ, CA, CO, GA, ID, MT, NM, NV OR, TX, UT, WA
Sheep	28	60	all seasons treatment	CA, CO, ID MT, NM, TX, UT, WY
Mule Deer	23	47	all seasons treatment	AZ, British Columbia, CA, CO, ID, MT, NM, OR, TX, UT
Whitetailed Deer	5	11	all seasons	AZ, MT, TX
Elk	10	17	summer, spring, fall	Canada, CO, WY, MT
Bighorn sheep	7	17	all seasons	AZ, British Columbia, CO, NM
Pronghorn Antelope	40	85	all seasons	Alberta, CA, CO, ID, KA, MT, NB, NV, OR, Saskatchewan, SD, TX, WY
Horse	6	8	spring-summer fall-winter	Alberta, CO, NM
Burro	3	8	all seasons	AZ, CA
Bison	4	16	all seasons treatment	Canada, CO

[a/] United States Postal Service code for states.

[b/] All season refers to spring, summer, winter, and fall.

[c/] Refers to studies with manipulation of grazing regime and/or augmentation of forage or pasture by fertilizer, etc.

Table D4. Number of species comprising 5% or more of the diet according to forage class compiled from 137 references. The first number in parentheses is the number within that forage class for that herbivore assigned a C_3 photosynthetic pathway, the second number, those assigned a C_4 pathway.

Herbivore	Grasses	Forbs	Shrubs	Other	Total
Cattle	77 (36, 34)	35 (12, 15)	17 (1, 1)	-	129
Sheep	33 (26, 5)	46 (16, 9)	23 (6, 4)	-	102
Mule Deer	10 (9, 1)	35 (14, 7)	72 (12, 9)	5 (3 CAM)	122
Whitetailed Deer	3 (1, 2)	10 (2, 7)	18 (2, 3)	4 (2 CAM)	35
Elk	17 (14, 2)	11 (5, 3)	17 (2, 1)	-	45
Bighorn Sheep	18 (9, 7)	10 (6, 3)	11 (2, 2)	-	39
Pronghorn Antelope	6 (3, 3)	13 (3, 6)	14 (4, 3)	-	33
Horse	13 (11, 2)	1 (0, 1)	2 (0, 0)	-	16
Burro	6 (3, 3)	2 (2, 0)	8 (0, 0)[a]	-	16
Bison	9 (6, 3)	1 (1, 0)	2 (1, 0)	-	12

[a] One shrub identified as having CAM photosynthesis.

7.0 SUMMARY AND CONCLUSIONS

Various methods of forage allocation decision making require an understanding of the actual or relative dietary botanical composition of herbivores grazing on the same rangeland. This information is required whether qualitative or quantitative methods of allocating forage are used and whether the quantitative method is an optimization model or some other approach. The dietary composition information may be converted into dietary preference information or it may be used directly in various methods of making forage allocation calculations.

In this paper we discuss briefly the methods of estimating dietary botanical composition, then we dicuss the C_3 - C_4 classification of grazingland plants as an aid to aggregating individual species into functional groups, then we present original and summarized information on dietary botanical composition of large herbivores grazing on western rangelands in the USA. The data presented represent unpublished information from the Bureau of Land Management as well as a summary and synthesis of information from the scientific and technical literature. Data are presented in considerable detail, to the species or plant group level. For those plant species or groups contributing 5% or more of the diet as measured in various investigations, the data are reported in quantitative values. For those plant species or groups making up less than 5% of the dietary botanical composition, simply the names of the plants or groups are given. In all cases, however, the data are classified as to animal species, location, season, and other information about treatments or grazing conditions.

Determining the diet of a free-ranging large herbivore requires first collecting a sample of what was grazed and then analyzing it. Samples may be collected by direct means, such as through the use of fistulated animals or through stomach samples, or by various indirect means. One indirect means is through the collection of fecal material from the rangeland to determine what was left in the feces after the plants passed through the digestive tract of the animal. Other indirect means are concerned with measuring what was grazed from the rangeland.

The use of esophageal or rumen fistulated animals appears to be the most accurate method available to collect an actual sample of what was grazed by the animal. Still, because the animals graze a highly selected mixture of plant species and plant parts and because they masticate this material to various degrees, there are problems in identifying or recognizing and thus reporting on a percentage weight basis the plant species or groups in the diet. The fecal analysis method is an excellent way to collect materials from the rangeland because it is relatively quick and inexpensive and can be adapted to a large number of animal species over many different habitats and seasons of the year. As with the samples taken from esophageal or rumen-fistulated animals, however, fecal samples do not lend themselves to easy identification of the dietary botanical components. Furthermore, there is a major problem of differential digestibility of different plants and thus differential retention in the fecal material of different plant species or groups as compared to the same items in the diet. Generally, there is a positive bias in the analysis of fecal sample results with respect to the estimation of percentage shrub content of the diet and a significant negative bias with respect to the forb components of the diet. In some research

studies there has been no significant correlation between the botanical composition derived from esophageal fistula forage samples and fecal samples from the same animals. We discuss in detail herein, with example numerical calculations, how differences in digestibility and recognizability can cause strong bias in estimates of diet composition. We feel that without further means of correcting or adjusting fecal analysis data, such data should be used only to determine the principal species constituents of the diet and, to a certain extent, the relative importance value of plant species or groups in the diet. In no case should a great deal of confidence be placed on the actual percentage composition values for plant species and groups derived from fecal analysis methodologies unless appropriate correction or adjustments are applied to the data.

Bite-count procedures have been used to study the diets of large herbivores. This method is relatively inexpensive, but cannot be readily adapted to many wild animal species. There is also a problem of converting bite-count information into a percentage weight measure.

Various methods of clipping grazinglands before and after grazing or in grazed and protected areas have been used to estimate utilization and hence diet composition of grazing animals. However, this method appears impractical to get statistically significantly data over large grazingland areas at many different seasons and at the levels of utilization imposed on rangelands, particularly the light use made by many large wild herbivores.

More work is needed to develop methods of double-sampling to combine more than one technique to study the dietary botanical composition of grazing herbivores. With such techniques, one combines a costly but precise and accurate methodology with another methodology which is less costly and less precise and accurate but can be more widely applied. By knowing the relationships between the two methodologies, sampling plans can be designed that are both statistically and cost efficient.

Analysis of samples collected by esophageal of rumen fistula or fecal material often requires microscopic determination of plant species or components in the diets. Also, analysis by field sampling of vegetation or by bite-count determination results in large numbers of species or groups in the diets. Statistical studies suggest that dietary botanical composition information, according to most commonly applied current methods, are probably valid to no more than a 5% level. That is, plants which are found at less than 5% in the diet probably could be considered only as traces. Probably those plants occupying 5% or more of the diet can be considered to be biologically and realistically significant components. Some workers suggest this figure may even be a 10 to 20%. In any event, this requires aggregating or grouping minor species or plants into larger categories for analysis and interpretation to readily identify and recognize the value of grouping plants into growth-form categories such as grasses and grasslike plants, forbs, and shrubs. Recently there has been much discussion of the C_3 and C_4 photosynthetic pathways found in different plant species. Plants with these two pathways are, more or less, similar to the resource manager's conventional classification of cool-season or warm-season growth habits. We discuss the various photosynthetic pathways of plant metabolism and their ecological significance and relate this to dietary botanical composition of large herbivores. Furthermore, we compile information on the photosynthetic

pathways of some 1585 plant species taken from 21 scientific literature sources. This classification is used in assigning individual plant species to functional groups based on growth season as well as on growth form.

We summarize herein previously unpublished data obtained from the Bureau of Land Management regarding the dietary botanical composition of large herbivores grazing on public lands. Most of these data were obtained by personnel in the Denver Service Center during the interval of 1977 through 1979 so they may be incomplete as relative to the present total data available. However, this compilation represents a valuable source of information and is presented in the form of averages of species composition in the diets of large herbivores as determined by collection and analysis of fecal material. The data are uncorrected for possible differential digestibility. Data are identified as to animal species, season of the year, and state and district.

A major contribution of this paper is the summarization of information on the dietary botanical composition of large herbivores as extracted from the scientific literature. These data are compiled from 137 scientific references in which the dietary botanical composition was reported quantitatively for one or more grazing herbivore on western rangelands for one or more seasons. The large herbivores considered are cattle, sheep, bison, bighorn sheep, pronghorn antelope, mule deer, whitetailed deer, elk, horses, and feral burros. In this compilation and tabulation in addition to defining the animal species and the location of the study we provide information on any specific season or treatment or stocking regime which was identified in the report. We also identify the method by which the dietary botanical composition was determined; these include: bite count, clipping or plucking, esophageal fistula forage sample analysis, fecal sample analysis, stomach analysis, ocular estimation or observation, and weight estimate methods. The plant names are identified according to Latin name as well as the standard SCS codes. The photosynthetic pathway of the plant is identified if known.

Some 49 sources of cattle diet botanical composition, producing 88 entries are summarized. Individual plant species often make up almost 60% of the diet of cattle in a single situation. In more than half of the references cited, shrubs were not a major component of the diets of cattle. In those cases where shrubs were a component of the diet they averaged about 25%. Overall, forbs averaged about 25% of the diet.

Some 28 references were found which were recorded as 60 entries in the table for dietary botanical composition for sheep. In these examples, shrubs averaged about 33% of the diet of sheep. In about half of the situations encountered, there was at least some forb use and in these cases the average was about 33% of the diet.

Analysis of the data available showed that: Bison were primarily grass eaters; over all grazing situations pronghorn antelope had a high proportion of forbs in their diets and also a considerable amount of shrubs; horses had a surprisingly high shrub component in their diets in certain situations but generally could be considered to be grass eaters; burro diets were highly site-specific and generally included a large number of individual plant species or groups in the diets; bighorn sheep diets are largely grass through forbs can be a major component in some seasons; deer take a wide variety of

plants in their diet with forbs or shrubs being important at various times; and elk show high shrub concentrations in the diet in the winter but heavy use of grasses in spring and summer.

CHAPTER E

A CRITICAL REVIEW OF PREFERENCE AND ITS CALCULATION

ABSTRACT

Animal preference for particular forage plants or forage classes is one of two of the measures needed to establish herbivore foraging requirements in optimization models for forage allocation. Preference is discussed in terms of consumer food requirements; preingestion and postingestion characteristics of the forage. These characteristics include moisture, mineral, protein and carbohydrate content, shape and texture. Many of these characteristics may be related to the photosynthetic pathway of the forage plant. Methods of preference determination which are essentially subjective in nature are examined as are methods which involve some data manipulation to arrive at a preference measure. Formulae for several preference indices are presented and discussed. A calculation of preference using six numerical indices on a common data set is presented. An index for the determination of preference, one which has a range from zero to one (a proportion), is recommended for use in optimization models.

CHAPTER E

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1.0 INTRODUCTION

Differential dietary preferences for forage species by large herbivores is a basic problem and opportunity for the range resource manager. The degree of competition is determined by the amount of consumption of each class of herbivore and the herbivore's preference for forage plants (Smith 1953). These two variables, consumption and preference, determine herbivore forage requirements and are an integral part of any for scheme to allocate available forage.

One of the tenets underlying the use of optimization models for forage allocation is that mixes of herbiores more efficiently (optimally) utilize the range resource than does just one herbivore. Thereby, increasing the overall number of herbivores present on the rangeland can maximize the use of forage species. The subject of consumption or forage intake rates has been dealt with elsewhere (Chapter C). The other variable, preference, is the topic of this chapter.

Reference is made to the Chapter A. In that chapter we present twelve optimization models which determine combinations of large herbivores that optimally utilize grazinglands. Models numbers 1 through 6 take the form:

$$\mathrm{MIN}\left[\sum_{i}^{Q}\left(\sum_{k}^{N}\left(H \cdot U_{ik}(S_{ik} + G_{ik})(1 - L_{ik}) - t_k \sum_{j}^{F} X_{jk} \cdot C_{jk} \cdot D_{ijk}\right)^{\text{Exponent}} \cdot W_{ik}\right)\right] \quad (1)$$

where 1 through Q is the range of plant groups i, 1 through F is the range of herbivore species j, and 1 through N is the number of seasons k. The exponent is either 1 or 2 depending on the desired degree of responsiveness to variable initial values one wants. The capability to weight the formulation is accomplished by W_{ik}. The available forage is expressed in terms of S the standing crop at the beginning of the season, G the gain in standing crop over the season, the allowable use U of plant species j, the size of the area under consideration H which is a constant and the complement of the loss (L) due to shattering, trampling, and decay. The forage requirement is expressed as the number of days in the k^{th} season t multiplied by the consumption or forage intake rate C for the j^{th} species in the k^{th} season. The decision variable X is the number of herbivores of each species allowed to graze the range. The variable D is the diet preference. As will be noted, D is the only variable in (1) with subscripts for plant species, animal species and season.

Incorporating a preference measure into equation (1) requires three assumptions:

(i) The preference of herbivore j for plant species i is not dependent on the number or kind of other herbivores on the range. That is, bighorn sheep preferences, for example, do not change when cattle and sheep are also resident or when the latter are absent.

(ii) Preferences do not alter in season k as herbage availability

changes. If a relatively gross approximation of optimal herbivore composition on the rangeland is required, this assumption obviates the need for consideration of herbage maturation and phenological stage. Obversely, if precise results from the model are required, this assumption can be negated by increasing the number of grazing periods, k.

(iii) Forage intake rates for each herbivore remain constant within season k. Again, should precise herbivore numbers be desired and should the manager wish to include varying forage intake rates, k may be increased to include different consumption rates. This latter however requires somewhat more information than is generally available as regards forage intake rates for large free-grazing herbivores (c.f. Chapter C).

With those assumptions understood, some working definition of preference is needed.

2.0 DEFINITIONS OF PREFERENCE

Considered conceptually, diet selection (e.g., preference) is related to variables that Ellis et al. (1976) call secondary control variables. These include the body size and metabolic body weight. These two variables dictate the energy requirements of the animal and can be modified by physiological state (resting, running, etc.) and reproductive state (pregnant, lactating, etc.). Ellis et al. (1976) likewise consider that ambient temperature modifies energy requirements. They also contend that there is a minimal or threshold amount of energy required for a consumer to maintain or increase its energy or nutrient balance called the consumer food requirement or CFR. This latter is dependent on the food quality (FQ) available, meaning the CFR will be met earlier in the grazing period if the food available is high in content of the requisite diet currency than if not. (Currency is used here to label the quantity of some requirement for which the herbivore forages. Usually this currency is energy stored in plant tissues (Emlen 1966, Pyke et al. 1977, Schoener 1971), but may also be minerals, nutrients and plant proteins, and during the dry season or in arid areas, water.) So, CFR is a function of ambient temperature (T), metabolic rate (MR), body size (W), physiological state (PS) and reproductive state (RS) as well as the quality of available food. For herbivore j feeding on plant species (or plant group) i:

$$CFR_j = f(MR_j, W_j, T, PS_j, RS_j, FQ_i) \tag{2}$$

Given relationship (2), then preference (D) must be tailored to satisfy the CFR. Visual cues, such as size and shape, color and presence or absence of thorns and inflorescences, etc. also contribute to forage selection. The relative abundance of a food vis-a-vie other foods (or novelty as Ellis et al. (1976) regard it) is a factor in selection. Thus, D of herbivore j for plant (group) i is a function of forage size (FS), forage novelty (FN), temperature (and perhaps humidity (H) which affects plant tissue turgor and hence taste, appearance and so forth). Or:

$$D_{ij} = f(FS_i, FQ_i, FN_i, RS_j, PS_j, T, H) \tag{3}$$

The above mentioned forage properties (size and shape, novelty and quality) cause either ingestion or rejection by the herbivore; they are detectable prior to ingestion. Other properties are detectable after digestion, and if unfavorable, preclude further ingestion of that forage item. These two properties are called sensory and nutritional properties respectively (Westoby 1974). The nutritional property which concerns plant constituents needs further discussion.

There are essentially three mutually exclusive responses a herbivore may have to characteristics of a forage plant once it is ingested: (i) a positive response, meaning the animal considers the plant palatible, (ii) a negative response, meaning the animal avoids the plant and (iii) a neutral response which implies the animal neither seeks out nor avoids a forage plant. The literature gives a number of examples of specific plant substances that can cause the above responses.

The following (partially from Marten (1969) and Westoby (1974)) have found that sugars and soluble carbohydrates elicit a neutral response from large herbivores: Warmke et al. (1952), Hardison et al. (1954), Reid and Jung

(1965), Reid et al. (1966), O'Donovan et al. (1967), Buckner et al. (1969), Rabas et al. (1969), Marten and Donker (1964). The following workers, however, found positive responses to the same substances: Cowlishaw and Alder (1960), Gangstad (1964), Bland and Dent (1962, 1964), Dent and Aldrich (1963), Heady (1964), Reid et al. (1967).

A neutral response to protein content was found by Archibald et al. (1943), Reid and Jung (1965), Reid et al. (1966), Reid et al. (1967), Buckner et al. (1969) and O'Donovan (1967), while protein content caused a positive response in work done by Hardison et al. (1954), Cook (1959), Blaser et al. (1960), Burton et al. (1964), Gangstad (1964), Heady (1964) and Fontenot and Blaser (1965).

Leigh (1961), Reid et al. (1966), Reid et al. (1967), Archibald et al. (1943), Buckner (1955) and Hardison et al. (1954) found a neutral response to crude fiber, acid detergent fiber or cell wall structure. Blaser et al. (1960), Gangstad (1964), Arnold (1964), Heady (1964) and Fontenot and Blaser (1965) establish that those substances produce a negative response in large herbivores.

Marten and Donker (1964) and Reid and Jung (1965) contend that mineral content produces a neutral response while Beaumont et al. (1933), Hardison et al. (1954), Ivins (1955), Cook (1959), Gangstad (1964) and Cowlishaw and Alder (1964) say that mineral content produces a positive response.

Other substances affect the animals' response to ingestion. Cook (1959) found that sheep respond negatively to cellulose concentration. Hardison et al. (1954) and Reid and Jung (1965) found no particular response to various vitamin content of foods. Buckner (1955) found a neutral response and Archibald et al. (1943) found a positive response to carotene concentrations in plants.

An hypothesis presented by Caswell et al. (1973) (who consider primarily only insects) is that herbivores evolved in temperate climates tend to avoid plants with the C_4-dicarboxylic acid pathway of carbon fixation. Presumably this avoidance is due to location and starch-storing functions of chloroplasts in C_4 species and to phloem and bundle sheath concentration and location. Evans and Tisdale (1972) document the preference of cattle, sheep and mule deer for the C_3 species Agropyron spicatum over the C_4 species Aristida longiseta. Though they did not specifically study carbon fixation pathways, their evidence supports the hypothesis of Caswell et al. (1973).

From the above, it is obvious that preference is not a simple consideration. Preference or selectivity or electivity (Ivlev (1961), Jacobs (1974)) is, as a consequence, difficult to accurately define. Stoddard et al. (1975) define preference as the selection of plants by animals. They contend that the term is often used incorrectly when "palatability" is meant. Palatability, they say, refers to the attractiveness of a forage, not its actual selection. This attractiveness is related to pre-ingestion cues, as mentioned above, such as taste, odor, texture of the plant and other visual stimuli (Westoby 1974). These two definitions and this distinction will be used in the remainder of this report. The contrast between preference and palatability is further discussed by Heady (1964) and Van Dyne et al. (1980).

3.0 PREFERENCE INDICES

A survey of the literature on forage preference by large herbivores yields the conclusion that many studies of forage intake rate or botanical composition of the diet try to account for and often measure forage preference. Measurements of forage preference are varied and are discussed in Section 4.0 of this chapter. There are, however, several numerical methods available for determining preference using an index. Such indices are detailed next.

3.1 Description of Indices

The work by Krueger (1970, 1972) uses four Relative Preference Indices or RPI's. Though these were not originally developed by Krueger, his notation is used here. The variables in his formulations are percent weight of a forage plant in the diet D (not the same variable as in equations (1) and (3)), percent frequency in the diet fd, percent weight of the forage plant in the overall range composition R, and the percent frequency of that plant on the range fr. The first index, RPI_1 is the percent frequency of a plant species or forage class multiplied by the percent diet composition divided by the percent frequency of a forage class or plant species on the range multiplied by the percent range composition. The expression is:

$$RPI_1 = (fd \cdot D)/(fr \cdot R). \qquad (4)$$

The second relative preference index is simply the percent diet composition divided by the percent range composition or:

$$RPI_2 = D/R. \qquad (5)$$

The third of Krueger's relative preference indices has the same numerator as (4), but that number is divided by the percent range composition R multipled by 100. The expression is:

$$RPI_3 = (fd \cdot D)/(R \cdot 100). \qquad (6)$$

The fourth RPI has the same denominator as (4), but the numerator is the percent diet composition multiplied by 100 or:

$$RPI_4 = (D \cdot 100)/(fr \cdot R). \qquad (7)$$

By inspection, it can be seen that the range of RPI's 1 through 4 is zero to plus infinity. It may also be seen that these indices are dependent on the size or number of the sample plots used to determine fr and R. Should a range survey be undertaken which misses a specific forage item while that item appears in the diet, these measures of preference lose their meaning. To overcome this shortcoming, the sample plot(s) must be increased in size. It is possible that a circumstance could be encountered where the entire range must be sampled in order to account for all of the forage items found in the diet.

In his analysis of relative preference values 1 through 4, Krueger (1972) rejected RPI_3 and RPI_4 because they do not allow equal values for forage plants when selection by animals is completely random. As may be seen, RPI_1

in equation (4) is the same for all species of forage when herbivores graze randomly. Equation (4) may be rewritten as:

$$fd \cdot D = RPI_1 \cdot fr \cdot R. \tag{8}$$

If, as Loehle and Rittenhouse (1980) point out, RPI_1 is known from previous studies and fr and R are obtained from range sampling, (8) yields a solution with two unknowns. Should one wish to predict preference and concomitantly diet composition, RPI_1 would not be sufficient.

The bounds of preference indices presented by Krueger (1972) present other problems. The value of infinity can be obtained when a rare plant species appears in the diet but is missed in the vegetation survey. Deriving a mean preference value for a plant species that has an infinite value in the data set is consequently impossible. Even very large preference values relative to other values bias a mean preference value calculation. Conclusions drawn from such calculations cannot be justified (Loehle and Rittenhouse 1980).

A probability index to measure preference has been proposed by Nelson and Burnell (1978). It is the probability that a herbivore will eat a plant when it is discovered. If U_i is the allowable use of herbage plant i, F_i is the diet composition or forage, and H_i is the percent range or herbage composition of plant species i, then the expression is:

$$\text{Probability Index} = F_i / \sqrt{H_i^2 + (H_i - U_i)^2}. \tag{9}$$

This formulation yields values between zero and positive infinity.

An optimization technique for forage preference prediction was proposed by Janisz and Van Dyne (1979). It took the form:

$$\text{MIN} \left[\sum_i \sum_s \left(F_{is} - (\sum_i F_{is}) \cdot \left(\frac{P_i R_{is}}{\sum_i P_i R_{is}} \right) \right)^2 \right] \cdot R_{is} = \frac{H_{is}}{\sum_i H_{is}} \tag{10}$$

where F_{is} is equal to the forage composition of plant i in sample s, H_{is} is the herbage composition with the same subscripts and P_i is the diet preference. This procedure uses a least-squares method to approximate preference values over a number of samples in order to reduce the difference between actual and predicted animal consumption. The range is 0 to +1.

That same progress report gives a formulation for the empirical multiplier method where preference is calculated as:

$$F = kH \cdot D_i = \sum_s ((k_i N_{is})/(T_s)) \cdot P_i = D_i / \sum_i D_i. \tag{11}$$

The variables in this formulation are: F, the matrix of forage plants i in sample s; k, a vector of multipliers for plant i; H, the matrix of herbage composition for plant i in sample s; D_i, a relative diet index; T_s, the total number of samples; N_i, the forage composition of an area different from that previously sampled; P_i, the diet preference. This expression yields values between 0 and +1.

Janisz and Van Dyne (1979) conclude that expressions (10) and (11) are time consuming and interpretation of results derived from them is complex. Their use is dependent on the benefit to be had by using the more precise results they yield. It may be that simpler formulations give the same results but with the expenditure of less time and effort.

The ratio of forage or food availability divided into the composition of the diet, for a specific food or forage item, was used early by Van Dyne and Heady (1965) in their study of sheep and cattle diets in California. Edmondson and Winberg (1971) also use a simple ratio of forage to herbage. Though they consider predator/prey relationships, their measure is equivalent to Krueger's RPI number 2 (equation (5)). Ivlev (1961) formulated an "electivity" index which is equivalent to the arithmetic ratio described in Section 3.2 of this chapter. Again, Ivlev was concerned with predator/prey interactions but his index is appropriate for studies of herbivory.

Jacobs (1974) considers both the simple ratio and the electivity index unsatisfactory because they do not allow the study of the correlation between relative abundance of food (forage) and food (forage) selection. He proposes instead that the log of the rate of food decrement due to feeding gives a better estimate of preference and is not responsive to changes in the composition of the food. Kautz and Van Dyne (1978) use the log of the simple ratio of forage to herbage in their calculation of preference.

Cock (1978) has criticized Ivlev's index saying that it is too dependent on prey (forage) densities and that, as a consequence, different situations are not comparable.

This review largely ignores the body of literature which describes foraging efficiency, behavior and modeling. Some selected works are cited here, should such topics be of interest: Pyke et al. (1977), Jones (1971), Emlen (1966), Schoener (1971), Timin (1973), MacArthur and Pianka (1966), Silen and Dimock (1978) and Caraco (1980).

The calulation of preference values using a common data set and six selected formulations is discussed next.

3.2 Calculation on a Common Data Set

Because of the drawbacks of using index calculations mentioned in the preceding section, we compare six preference measures based on a common data set. The data is from a northeastern Colorado shortgrass prairie rangeland and is reported in Van Dyne (1978). We have used the light grazing regime, the data for which is shown in Table E1. It will be noted that the data is for different herbivores: cattle, bison, sheep, and pronghorn antelope, and is presented according to forage class, i.e. grass, forbs and shrubs. Cattle, in this study, consume primarily grass (93%), some forbs (8%) and almost no shrubs (<1%). Bison consume 70% grass, almost 30% forbs and very little of shrubs (1%). Sheep on the Pawnee site in eastern Colorado consumed 41% grass, 3% shrubs and had the major portion of their diet derived from forbs (52%). Approximately 4% of the sheep's diet was other plants. Pronghorn antelope ate less than 1% shrubs, some grass (13%) and consumed 87% in the forb category.

Table E1. Herbage and diet botanical composition by percent dry weight of four herbivores used for calculating forage preferences. (Data from Van Dyne 1978)

Item	Animal Species	Grasses	Forbs	Shrubs
Herbage		75	10	15
Diets	Cattle	93	8	<1
	Bison	70	29	1
	Sheep	41	52	3
	Pronghorn Antelope	13	87	<1

The six preference indices used in the common calculation are as follows. The first index is called here the "Simple Ratio", and is the amount of a forage (F) of a particular class (or species) i in the diet divided by the amount of herbage (H) of a particular class (or species) i found on the range. It is similar to the index developed by Van Dyne and Heady (1965) and analogous to the measure of Edmondson and Winberg (1971). Thus, the Simple Ratio (SR) for a forage class i is:

$$R_1 = SR_i = (F_i + 0.01)/(H_i + 0.01). \tag{12}$$

(The addition of the term 0.01 insures that no division by zero will occur should the H_i be zero because the range survey failed to find any of a particular rare class of plant or plant species on the range.)

The second method of preference calculation (R_2) is simply the natural logarithm of SR_i or:

$$R_2 = \ln(SR_i). \tag{13}$$

The third preference calculation (R_3) normalizes the Simple Ratio so that when summed over i (all forage classes or forage species) the result is unity. Mathematically the expression is:

$$R_3 = \frac{SR_i}{\sum_i SR_i}. \tag{14}$$

The fourth preference calculation method (R_4) normalizes the log of the Simple Ratio, again so the sum of all the ratios is one. This is expressed as:

$$R_4 = \frac{\ln(SR_i)}{\sum_i \ln(SR_i)}. \tag{15}$$

A fifth method of preference calculation (R_5) utilizes the so-called arithmetic ratio of herbage to forage. This is also Ivlev's electivity index. It requires subtracting the herbage on the range from the forage in the diet for each forage class and dividing the difference by the sum of the forage in the diet and the herbage on the range for each forage class. The expression is:

$$R_{5_i} = \frac{F_i - H_i}{F_i + H_i}. \tag{16}$$

As may be seen, the arithmetic ratio, R_5, yields values in the range of -1 to 1 inclusive. Using (16), a value for R_5 of one is interpreted as 100% selection for a plant or plant group; a value of zero, selection neither for or against a plant or plant group; a value of minus one, 100% rejection of a plant or a plant group.

The sixth method of forage preference calculation might be to normalize the values of R_5. Recall however that equation (1) requires preference D in the k^{th} season by herbivore j for plant group i to be a proportion or percentage within the range zero to one. In order to put the values of R_5 into the requisite range, one is added to each $R5_i$ value and the resultant value normalized. The sum, then, of all the preference values for one herbivore species is unity. The expression is:

$$R6_i = \frac{R5_i + 1}{\sum_i^n (R5_i) + n} \quad . \tag{17}$$

The results of these six calculations using the data in Table 1 are presented in Table E2.

The results of the calculations shown in Table E2 essentially show the trends of Table E1. That is, cattle have the highest preference of all the herbivores for grasses under the column for the simple ratio, the log of the simple ratio, the normalized ratio and the log of the normalized ratio. Bison show the second highest preference for grasses under those four preference measures, with sheep and pronghorn antelope following, in that order. Pronghorn antelope show the highest preference in the first four columns for forbs, as would be expected from the raw data, followed by sheep, bison and cattle for that forage class.

The calculation of preference using the arithmetic ratio yields what may appear to be puzzeling results. Cattle, for example, chose a diet composed of 93% grasses, yet the arithmetic ratio produces a cattle preference for grasses of 0.11. That value seems rather low in view of the raw data. The matter is explained however when one considers that the arithmetic ratio calculates preference simultaneously for all forage and herbage classes. A preference value calculated by this method then must be evaluated in relation to all other preference values for a particular herbivore species. Viewed in this context, the seemingly low cattle preference for grasses is indeed rather large when compared to cattle preference for shrubs calculated by equation (16).

The values shown under the normalized arithmetic ratio heading, scaled between zero and one, show the same tendencies as do those values in the previous column. Remember these values are reduced by half, so the differences between any two values for a particular herbivore are in fact double what is shown.

The need for incorporation of a preference value scaled as is R_6 into the optimization formulation of (1) is evident. This exercise of calculation of preference values on a common data set shows there are a number of formulations available should a measure of preference be required in natural resource management. As is shown in the next section, those measures discussed above are not the only such measures available. One problem with this plethora of preference measures is deciding which one to use, and designing the experiment or study so that the proper data are gathered. It is necessary, too, to insure that the index used answers the questions posed in the design of the

Table E2. Comparison of preference values using six methods of calculation.

ANIMAL	FORAGE CLASS	SIMPLE RATIO	LOG OF SIMPLE RATIO	NORMALIZED RATIO	LOG OF NORMALIZED RATIO	ARITHMETIC RATIO	NORMALIZED ARITHMETIC RATIO
Cattle							
	Grasses	1.24	0.22	0.59	-0.53	0.11	0.52
	Forbs	0.80	-0.22	0.38	-0.97	-0.11	0.42
	Shrubs	<0.07	<-2.66	<0.03	<-3.51	<-0.88	<0.06
Bison							
	Grasses	0.93	-0.07	0.24	-1.43	-0.04	0.37
	Forbs	2.90	1.06	0.74	-0.30	0.49	0.58
	Shrubs	0.07	-2.66	0.02	-3.91	-0.88	0.05
Sheep							
	Grasses	0.55	-0.60	0.09	-2.41	-0.29	0.26
	Forbs	5.20	1.69	0.87	-0.14	0.68	0.62
	Shrubs	0.20	-1.61	0.03	-3.51	-0.67	0.12
Pronghorn Antelope							
	Grasses	0.17	-1.77	0.02	-3.91	-0.71	0.13
	Forbs	8.70	2.16	0.97	-0.03	0.79	0.81
	Shrubs	<0.07	<2.66	<0.01	<-4.85	<-0.88	<0.06

study. If for example, the simple ratio is used, inferences about the relationship between preferences for one forage plant as opposed to another may not be answered should the experimenter require the simultaneous relationship.

The next section considers other means of calculating preference as found in the scientific literature.

4.0 LITERATURE SUMMARY OF PREFERENCE

Determination of forage preference by large herbivores need not involve the use of mathematical formulae nor extensive manipulation of the data. Examples of such preference determinations are detailed in this section.

4.1 General Considerations of Preference

Examples from the literature in which preference is measured largely on a subjective basis follow. These measures of preference have their value in resource management although they are perhaps the least elegant of the methods considered herein. The one feature which recommends their use is the ease with which they may be determined.

Nineteen precis of papers where preference is determined are grouped according to several categories and are shown below. There are six broad categories which are:

(i) % time grazing -- Smith and Hubbard (1954) offered browse species to tame deer in feeding trials. They ranked the forage species according to time spent by the deer browsing and according to the weight of forage consumed. The ranking was labeled preference. Stormer and Bauer (1980) considered the time spent by tame deer in various forest stands of differing plant species composition a measure of habitat preference. Healy (1971) established high, medium and low preference ratings for tame deer fed clipped forage. The ratings were determined by comparing the percent of time a deer spent eating a plant species with the percent of its weight in the sample.

(ii) % grazed plants -- Crouch (1966), working with black-tailed deer, simply counted leaves and twigs browsed in sample plots to get a cumulative percent browsed of the available forage plants. This was termed preference. The study by Hurd and Pond (1958) measured utilization of forage species as percent weight removed in sample plots. Preference ratings were derived from these utilization estimates. Herbel and Nelson (1966) tested for preference differences between Hereford and Santa Gertrudis cattle on New Mexico ranges. Their measure of preference was the percent of the total of all observations a species of forage plant was grazed. Dwyer et al. (1964) considered percent of plants grazed as an index to forage preference in their study of steer preferences.

(iii) animal presence or density -- Reardon et al. (1978) consider the density of deer on various rangelands grazed by livestock on a deferred rotational basis. They contend that the number of deer present on different rangelands indicate a species preference for that grazing system. Coleman et al. (1971) consider that selective grazing by herbivores, in this instance cattle, constitutes preference. They correlated preference to chemical constituents of the forage plants. Miller (1968) considered preference as the ratio between the

percent of deer of the total deer sighted in each plant community and the frequency of occurrence of the plant community.

(iv) plant use -- Beale and Smith (1970) studied pronghorn antelope in western Utah. By using some rumen samples and random observations of feeding sites and occular estimates of use on sample plots, they determined utilization of forage species. By ranking the utilization figures from low to high they established a preference rank. Korschgen et al. (1980) considered utilization the same as preference as long as deer populations remain within the carrying capacity of the land. Severson and May (1967) also consider utilization synonymous with preference, but their study dealt with antelope and domestic sheep. For their study of deer and cattle, Drawe and Box (1968) obtained preference values simply by multiplying percent frequency of a forage plant on the range by the percent utilization.

(v) simple mathematical relationship -- Heady and Torell (1959) sampled the botanical composition of study plots and the extrusa of esophageally fistulated sheep. The contribution in percent of the diet compared to the percent contribution to the grasssland of a particular forage species constituted preference. McCaffery et al. (1974) determined preference by multiplying the percent volume of a plant species in the diet determined from rumen extrusa analysis by the percent occurrence of the plant species in the diet (i.e. frequency). Bedell (1968) used the difference between forage percent in the diet of cattle and sheep and the forage on the rangeland, the latter determined from clipped plots, the former from fistulated animals.

(vi) other measures -- Longhurst et al. (1979) offered forage to caged animals in cafeteria feeding trials. Based on the selective feeding of the sheep and deer used in the study they established a preference rank of preferred forage species. Their intent was to determine palatability of the browse species in the study area. (Note here that the word palatability may be used improperly.) In eastern Colorado, Reppert (1960) dealt with forage preferences in cattle. His observations of grazing heifers were based on mouthfuls of forage. He determined preference by the percent composition each forage plant species contributed to the total forage consumed.

The above papers and the procedures for preference determinations explained in them lack a certain rigor in those preference determinations. The next subsection considers examples of preference determination which involve somewhat more manipulation of the data.

4.2 Examples of Calculated Preference Values

Other workers use some means or method to establish preference values or ranks of forage species in herbivore diets. These studies do not necessarily calculate preference using an index as discussed in Section 3.0 above, but some relationship between forage plants and animal preference is established. These methods include:

(i) availability or availability factors -- Drawe (1968) and Everitt and Drawe (1974) used an availability factor in their determination of preference. The factor was arbitrarily set at 1 for rare, 2 for occassional, 3 for frequent and 4 for abundant occurrence of a forage plant on the range. The factor was then divided into the product of the percent frequency of occurrence and the percent volume of the forage plant in the diet. Chamrad and Box (1968) sampled the range of south Texas and took rumen samples from white-tailed deer. Their preference value was calculated by multiplying percent frequency in a rumen sample times the percent volume in the rumen sample of a forage plant. The preference rating they used took the preference value and divided it by an availability factor determined from range sampling. Krausman (1978), in his determination of preference for mule deer and white-tailed deer in Texas first calculated an availability number by multiplying the frequency times the percent density of the plant in the field. The range on this value was zero to 10,000. Preference was then calculated as percent frequency times the percent volume in the rumen divided by availability.

(ii) forage weight in the community -- The percent contribution of each forage species in the diet divided by the percent by weight of that species in the community was the method whereby Collins et al. (1978) determined preference of elk for forage. This same method was used by Deschamp et al. (1979).

(iii) relative preference index -- Krueger et al. (1974) used RPI_1 (see Section 3.1 above) to measure preference in sheep as related to taste, touch, smell and sight of forage plants. Uresk and Rickard (1976) used the same relative preference index for their study of steer diets in south-central Washington.

(iv) site use -- Stevens (1966) recorded instances of use of forage species, one instance being one bite, of cattle, sheep and elk. Preference was established as seasonal or vegetation type use as an average of aggregate percent use per site divided by percent of sites on which an item was used in relation to all sites in that category. Martinka (1968, 1969) used an aggregate percentage method to determine preference of white-tailed deer, mule deer and elk. In the 1968 paper, rumen analysis indicated diet botanical composition. In the 1969 paper, feeding sites were examined for instances of use of plant species. The preference index was then calculated as

the average percent use of all plants used per site divided by the percent of sites (within a plant community) in which a specific taxon was used.

(v) averages -- Marcum (1979) studied the food habits of a Montana elk herd in the summer and fall. His preference values were derived from dividing average relative plant utilization for each plant species by the average absolute cover of that species for all study plots measured during a given month. Smith (1953) studied captive mule deer and fed them selected forage from that available in the study area. Over a total of seven trials and a period of five months, he established preference values for some 32 forage plants by dividing the average consumption of any species during a period by the average daily forage intake during the corresponding period. Lay (1967), studying deer range in eastern Texas, measured utilization of growth on sample plots. These measures were then used to determine palatability ratings. A "utilization mean" was then derived by dividing the percent utilization readings by the number of plots in which they occurred. The means were then combined into a mean index for each group or forage class (browse, pine, grasses, etc.).

(vi) statistical tests -- Clary and Pearson (1969) studied cattle preferences for forage species in northern Arizona. Their measure of preference compared actual forage species use to a base or standard species. They tested for significant differences between the two with covariance analysis. Tomanek et al. (1958) used a chi-square test to determine if cattle were grazing any of six mixed prairie grasses in other than random fashion. They correlated results of this test with percent occurrence of species on each site, percent of grazed samples on each site and the number of times a species was grazed in relation to the number of times that species was present on a transect. From these observations they established three classes of preference, significant negative preference, significant positive preference and no significant preference.

(vii) other methods -- Oldemeyer et al. (1971) examined feeding sites to determine relative frequency of grazing. They then calculated an index of preference by dividing the percent of a species to be grazed or browsed by its percent plant cover.

Sections 4.1 and 4.2 are intended to point out the wide variety of essentially non-numerical techniques that have been used to determine forage preferences of large herbivores. Our review, while not complete, does show that the methods of obtaining forage preference values are as varied as the number of studies which include preference. The one disturbing feature of all this preference determination work is that values for preference obtained in one study determined by one methodology may not be compared with preference values (often for the same plant or herbivore species) derived in a second study. This problem precludes evaluation of preferences across many studies and is a cogent reason for standardizing preference value determination methodologies.

5.0 CONCLUSIONS

The survey of the literature on forage preference, its measure and calculation has indicated that there is interest in measuring and predicting forage preference and that seemingly every study has a way of doing so. The problem presented by this fact is preferences calculated in one study cannot be used elsewhere. Because the ranges of the values calculated for preference vary, depending on which of several numerical formulae one uses to calculate preference, transfer of values and conclusions from one study to another is impossible if two different methods of calculation are used.

The recommendations are obvious. A standard preference index needs to be adopted which is acceptable by reason of index range, ease of calculation, ease of required data gathering and agreed-upon interpretation. Arguments for and against such an index must be clearly elucidated so that users can know the limitations of the index. Once this is accomplished, subsequent studies can be compared and contrasted as regards preference. Allowance for temporal changes in preference will have to be made. Krueger et al. (1974) have shown, preference can change over time while range composition changes or preferences can change markedly while herbage composition change is small.

This review has cited a number of studies where preference is judged to be a rank of utilization or consumption or a simple ratio of some field measurements of the above. After a standard index is adopted, preference values in earlier studies need to be calculated again. This, of course, would be a formidable task as not all studies report data from which their preference values were calculated. Still some back-calculation could be done and were possible, original data obtained by requests to workers over the telephone or via the mails.

The preference index favored at the moment for incorporation into the optimization formulation of equation (1) is a normalized index with a range from zero to one as is shown in equation (17).

CHAPTER F

RESULTS AND COMPARISONS OF ALTERNATIVE MODEL STRUCTURES

ABSTRACT

The forage allocation problem involves selecting the optimal numbers and species of animals to be grazed on a given grazingland such that forage use is maximized. At the same time there are constraints to overgrazing any individual important plant species, to leave sufficient vegetation cover as protection of the soil from wind and water erosion or to manipulating animal numbers seasonally in an impractical manner. The problem can be formulated as a mathematical programming optimization model. A variety of linear and nonlinear programming formulations can be used to aid in resource management decision making. This paper presents original formulations, analyses, and interpretations of optimization models for forage allocation. Detailed mathematical formulations are provided along with an extensive set of narrative conclusions about this area of work. Models that are formulated and solved herein using a real-life data set vary from linear, single-season, deterministic models up to more realistic but more complex models that are nonlinear, multiple-season, weighted-objective function, and the deterministic equivalent of stochastic models with chance constraints. Six main optimization model structures were applied to a common data set for comparison wherein four animals species were available, two domestic and two wild, and the plant species available were aggregated into warm-season grasses, cool-season grasses, warm-season forbs, cool-season forbs, and shrubs. In the multiple-season models the year was subdivided into seasons of spring, summer, fall, and winter for the optimization analyses. The most complete model formulation incorporates a wide variety of biological and technical information. Stochasticity in these models refers to the use of chance constraints which reflect possible uncertainty in the random variables entering into the model. The objective is to minimize the amount of herbage remaining after grazing. This depends on the total amount of herbage available before grazing which in turn depends upon the number of hectares in the grazing area, allowable use factors for plants, beginning standing crop of vegetation plus a growth increment, and vegetation loss due to natural causes other than grazing. The amount of herbage grazed is calculated from the number of days the animals are on the grazingland, the total forage intake requirement of the animals per day, the relative dietary preference (used to calculate diet composition), and the unknowns, i.e., the numbers of different animal species to be grazed in different seasons. Considering four grazing seasons and five plant groups, there are four site maintenance constraints, 20 different overgrazing constraints representing five plant species and four time intervals. In addition upper and lower limits can be specified on each of the four animal species in each of the four seasons. Several areas of further work or needed information were identified. These include, but are not limited to, improvements in model formulations particularly for including spatial influences in problem formulation and in formatting output for ease of use by resource decision makers, obtaining a better understanding of dietary preference and composition of grazing large herbivores, and developing a better way to calculate or understand herbage losses at different seasons on different grazinglands.

CHAPTER F

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1. INTRODUCTION

Several optimization models and their variations are presented in Chapter A. We consider these formulations potentially feasible methods of determining forage allocated to large herbivores. The models range from the very simple linear single-season formulation, with several inherent simplifying assumptions, to the more complex formulations which have incorporated in them random variables. They also require fewer simplifying assumptions.

1.1 Summary of the Conceptual Model Form

The general conceptual model can be stated as minimizing the remaining available herbage following grazing or maximizing the grazed forage, both in terms of kilograms of phytomass. Either of the above structures, maximizing or minimizing, is derived through the actual implementation of the following expression:

$$\text{minimize } [\Sigma_{i=1}^{I}\Sigma_{n=1}^{N}((A_{in}-\Sigma_{j=1}^{J}X_{jn}R_{ijn})^{\text{Exponent}}\cdot W_{in})] \qquad (1)$$

where:

$$A_{in} = HU_{in}(S_{in}+G_{in})(1-L_{in})$$

$$R_{ijn} = T_nC_{jn}D_{ijn}$$

$W_{in} = A_{in}$: model 3, 5B, and 6C
1: models 1, 2A, 2B, 4, 5A, 5C, 6A and 6B

Exp = 2: models 4, 5C, 6B and 6C
1: models 1, 2A, 2B, 3, 5A, 5B and 6A.

All the above variables are known, with the exception of the X's, the herbivores, which are the decision variables, and the standing crop, S's, after the first season. (For a definition of the variables, symbols, and notational conventions used throughout of this chapter, refer to Appendix A.

From the conceptual form of the model (1) six basic groups of model formulations are derived and implemented. The characteristics of these models are shown in Table F1.

1.2 Objectives

The purposes of this chapter are to: 1) derive the standard form models from the conceptual model (1); 2) implement the standard form models; 3) describe a common data set used for the evaluation of the models and the information requirements of the models; 4) discuss the special problems associated with the stochastic models and the assumptions made of the distributions of the variables used in the models; and 5) discuss the model results or the common data sets in terms of both biological and management implications.

Table F1. Comparison of model structure with various objective functions with equivalent sets of deterministic or chance constraints and the code types used to solve them for allocation of forage to four animal species.

MODEL CHARACTERISTICS					
Model	Linearity	Seasonality	Weighting	Constraints	Code Type
1A, 1B	linear	single	non-weighted	deterministic	LPP
2A, 2B	linear	multiple	non-weighted	deterministic	LPP
3	linear	single	weighted	deterministic	LPP
4	quadratic	single	non-weighted	deterministic	QPP
5A1, 5A2,	linear	single	non-weighted	deter. & chance (20, 40, 60, 80, 90, 95, 99%)	NLPP
5B	linear	single	weighted	deter. & chance (20, 40, 60, 80, 90, 95, 99%)	NLPP
5C	quadratic	single	non-weighted	deter. & chance (20, 40, 60, 80, 90, 95, 99%)	NLPP
6A1, 6A2,	linear	multiple	non-weighted	deter. & chance (20, 40, 60, 80, 90, & 95%)	NLPP
6B	quadratic	multiple	non-weighted	deter. & chance (20, 40, 60, 80, 90, & 95%)	NLPP
6C	non-linear	multiple	weighted	deter. & chance (20, 40, 60, 80, 90, & 95%)	NLPP

Several different kinds of variables are used in the models. This poses special problems in making assumptions about the distributions of these variables. These are discussed below.

2. DISTRIBUTIONS OF THE VARIABLES USED IN THE MODELS

A variable may be defined "as a property with respect to which individuals in a sample differ in some ascertainable way" (Sokal and Rohlf 1969). Our models make use of nine different classes of parameters, of which two are constants, three are continuous variables, and four are derived variables. In addition to these, there are three additional classes of constants unique to the right-hand side of some constraints.

The parameters H and T are constants and are therefore without distributions. The parameter H represents one constant in all the models. The parameter T represents one constant in the single-season models and four constants in the multiple-season models.

The parameters S, G, and X are represented as continuous variables where S and G are measurement variables and X is a decision variable. The parameters S and G each represent 5 (single-season) or 20 (multiple-season) continuous measurement variables, while X represents 4 or 16 continuous decision variables in the single-season or multiple-season formulations, respectively. Decision variables represent those variables that the optimization models select for through evaluation of the model's objective function, subject to its constraints. The continuous measurement variables S and G are treated as random variables in the stochastic models and are assumed to be normally distributed. The validity of such assumptions is questionable, but they are the simplest assumptions that can be made until further work in the area of estimating and predicting these variables shows otherwise. However, given any data set used to estimate S and G, a variety of statistical test, such as a runs test, can be used to validate an assumption. Once it is deemed that all the quantities of:

$$E_i = A_{in} - b_i \leq 0 \text{ for } i=1,\ldots n$$

which represents any inequality constraint, have finite means and variances, then by the central limit theorem, the quantity:

$$(A_i - E(A_i))/VAR[A_i]$$

will tend to a unit normal variate, N(0,1) if the variables sufficiently approximates the normal distribution (Sengupta 1972).

Thus, the transformation of a deterministic constraint into a chance-constraint (discussed later in sections 3.2.5 and 3.2.6) is made more easily if normality of random variables can be assumed. Furthermore, the penalty function of the chance-constraint is fairly robust in its assumption of normality.

The parameters U, L, C, and D are derived variables. The derived or computed variable generally stems from at least two or more independently measured variables versus the continuous measurement variable which is a single observation of a direct measurement of some material. The derived variable can be expressed as a ratio, proportion, percentage, index, or a rate, to name a few. The variables U, L, and D are proportions, or normalized

ratios. As such, they represent pure numbers, dimensionless, free of association with any kind of unit. The variable C is a rate, which is also a ratio (mass/time), but differs from U, L, and D in that it is associated with the physical units of mass and time.

There are several disadvantages associated with derived variables, two of which are of particular concern here. The first disadvantage is their relative inaccuracy. For example, consider a ratio similar to U, L, and D; 2.3/3.9. The measurement of 2.3 and 3.9 implies a true range of measurements from 2.25 to 2.35 and 3.85 to 3.95, respectively. Therefore, the true ratio may vary from 2.25/3.95 to 2.35/3.85 or .570 to .610. The maximal possible error in the above ratio is 7.2% as compared to 2.6% and 4.4% for the measurements of 2.3 and 3.9, respectively.

The second major disadvantage of derived variables is in describing their distribution. Ratio, proportion, and percentage variables generally have very unusual distributions and, therefore, rarely if ever, resemble a normal distribution. Such variables can be transformed into normal distributions by using the arcsine transformation. In doing so, all ratio variables are homoscedastic throughout, that is, they all have the same parametric variance, the constant 820·8.

It would be inappropriate to use arcsine transformed variables in our models in order to treat them as normally distributed variables. First of all, the transformed variables would be of no use to the model's properly intended evaluation of the objective function and the constraints. Secondly, the transformed variables' distribution would all have the same parametric variance and, therefore, the models could not address questions concerning differing degrees of variation in U, L, or D. Lastly, the normal distribution obtained through transforming the variables would only be indicative of the properties of derived variables and not at all indicative of the properties inherent in the original continuous measurement variables used to derive U, L, and D. Therefore, due to the anomalies of derived proportion variables U, L, and D will be treated as constants.

As mentioned above, the derived variable C differs from U, L, and D since it is associated with physical units. Hence, C can be considered normally distributed if one can assume the original measurement variables, mass and time, are randomly distributed since the quotient of two random variables is also a random variable. However, one can not accurately determine the true distribution of C without knowing the distributions of the mass and time unit variables and thereby derive the distribution of C precisely as the quotient of those two continuous variables. If the measure of time can be considered as a constant by using the same period of time to measure the ingested mass, the calculation can be made simpler such that:

$$\mathrm{VAR}[C] = \left(\frac{1}{(\mathrm{time})^2}\cdot \mathrm{VAR}[\mathrm{mass}]\right)$$

versus treating them both as random variables.

In either case, C can be treated as a random variable providing we assume that at least the original mass measurement used to derived C is randomly distributed. The same assumption can be made for the variables S and G as

well. Evidence at present seems to conform with these assumptions since it suggests that intake rates of cattle and sheep, the two domestic herbivores considered in the models, are normally distributed (Chapter C).

In summary, the random variables, assumed to be normally distributed are S, G, and C, which represent the standing crop (for n=1 only), the growth in the standing crop, both in kg/ha, and the consumption rate of the herbivores in kg/day, respectively. The remaining variables H, U, L, T, and D are treated as constants.

3. STANDARD AND NUMERICAL FORMS OF THE FORAGE ALLOCATION MODELS

The forage allocation models, considered herein, are conceptual in form. As such, a conceptual model must be transformed into the standard form model of the particular type of algorithm chosen to solve the model. The complexity of the process can range from the very simple to the very complex depending on how well the conceptual form model resembles that of the standard form model. Generally, though, the more complex a conceptual model is the more complex is the transformation to a standard form model.

3.1 The Standard Form Models

The models considered are solved by algorithms which are of three different types. Accordingly, three kinds of standard form models are used. These are the Linear, Quadratic and Non-Linear Programming Problem Standard Forms. Both the Linear and Quadratic Standard Forms are in a matrix form, and as such, represent the "true" standard form algorithms.

3.1.1 The Linear Programming Problem

The Linear Programming Problem (L.P.P.) is a mathematical program which consists of a linear objective function which is constrained by a system of linear constraints in the form of equalities or inequalities. The actual form of these constraints vary in different conceptual models but any linear programming problem can be transformed into the following standard form model:

$$
\begin{array}{lll}
\text{minimize} & c^T x & \\
\text{subject to} & Ax = b & x \in E^n \\
 & x \geq 0 &
\end{array}
$$

where x, the unknown or decision variable vector, is defined as an n column vector belonging to an n-dimensional Euclidean space and denoted by E^n. The row vector, c^T, represents the cost coefficients of the objective function. The m x n matrix A and the column vector b are the fixed real constants of the system of constraints. The vector inequality, $x \geq 0$, states that each component of x is non-negative.

Inequality constraints may be incorporated into the L.P.P. by the addition of slack and surplus variables. For example, by the addition of the positive variable y_i to take up the "slack" in the less than or equal to linear inequality. So:

$$a_{11}x_1+a_{12}x_2+a_{13}x_3 \leq b_1$$

$$a_{21}x_2+a_{22}x_2+a_{23}x_3 \leq b_2$$

can be transformed into an equivalent equality expression:

$$a_{11}x_1+a_{12}x_2+a_{13}x_3+y_1 \quad = b_1$$

$$a_{21}x_1+a_{22}x_2+a_{23}x_3 \quad +y_2= b_2.$$

The greater than or equal to inequality:

$$a_{11}x_1+a_{12}x_2+a_{13}x_3 \geq b_1$$

$$a_{21}x_1+a_{22}x_2+a_{23}x_3 \geq b_2$$

may be transformed as well to a linear equality expression by the use of the negative variable y_i to take out the "surplus" of the inequality. This results in:

$$a_{11}x_1+a_{12}x_2+a_{13}x_3-y_1 \quad = b_1$$

$$a_{21}x_1+a_{22}x_2+a_{23}x_3 \quad -y_2= b_2.$$

A maximization problem can be easily transformed to a minimization problem by simply multiplying all of the cost coefficients of the objective function (i.e., the c's) by negative unity. Many algorithms available for solving L.P.P.'s automatically put in slack and surplus variables as well as converting maximization problems into minimization problems.

Thus, the L.P.P. algorithm may be used to solve linear objective functions constrained by linear equality or inequality constraints constraints through the use of slack and surplus variables.

3.1.2 The Quadratic Programming Problem

The Quadratic Programming Problem (Q.P.P.) is a mathematical program consisting of a quadratic objective function subject to linear inequality constraints. The standard form of the Q.P.P. is:

$$\text{minimize} \qquad F(x) = 1/2x^TQx+c^Tx$$

$$\text{subject to} \qquad Ax\leq b \quad x \in E^n$$

where x, as before, is the decision variable vector, c^T is the cost coefficient vector, the matrix A and the vector b are the fixed real constants all of which are the same components as those of the L.P.P. The n x n matrix Q is the hessian and represents the quadratic terms of the objective function. The quadratic function may be decomposed into an n x n hessian, Q, and a row vector c^T by inspection or by partial derivatives:

$$Q_{ij} = \frac{\partial F^2}{\partial x_i \partial x_j}$$

$$C = \nabla F(x)\Big|_{x=0}.$$

Thus the hessian, Q, is a n x n symmetric matrix of second order partial derivatives with respect to x and the vector c is obtained through the gradient of F(x) with respect to x, evaluated at zero.

The Q.P.P. does not allow for equality constraints and therefore all such constraints must be substituted out of the constraint system and the objective function. This is accomplished by expressing the equality constraint as a function of one of the decision variables which is then substituted out of the problem entirely. The values of the substituted decision variables are then determined by means of the original equality constraint with knowledge of the decision variables which where solved for by the solution algorithm.

The implicit non-negativity constraint for a decision variable is lost when it is substituted out of the problem. If it is possible for a non-free decision variable to take on negative values then the derived expression for the substituted variable may be used as an additional explicit non-negativity constraint.

3.1.3 The Non-Linear Programming Problem

The Non-Linear Programming Problem (N.L.P.P.) is a mathematical program consisting of a non-linear objective function constrained by linear or non-linear constraints. The standard form of the N.L.P.P. is as follows:

$$\text{optimize} \quad g_k(X) \qquad X \in E^n$$

subject to

$$\text{lower bound } (n+i) \leq g_i(X) \leq \text{upper bound } (n+i)$$

$$i = 1, 2, \ldots m$$

$$i \neq k$$

$$\text{lower bound } (i) \leq X_i \leq \text{upper bound } (i)$$

$$i = 1, 2, \ldots n$$

where X is the decision variable vector; optimize refers to the minimization of convex functions or the maximization of concave functions. Equality constraints may be used as well as inequality ones. The N.L.P.P. algorithms differ principally from the L.P.P. and Q.P.P. "standard form" algorithms in two ways: 1) they solve for an optimal solution subject to constraints by methods of approximation whereas the "standard form" algorithms solve for algebraically "exact" solutions (except for computer derived discretinization error); 2) they utilized computer coded (generally FORTRAN) subroutines, supplied by the user, to evaluate the objective function and constraints and/or the gradients and Hessian thereof.

Thus, instead of doing matrix manipulations to pivot for increasingly better basic feasible solutions, as is the case of the standard form algorithms, the N.L.P.P. algorithms generally follow the following simplified scheme: 1) attempt to find a basic feasible solution if the user supplied starting point violates any of the constraints or bounds; 2) determine a feasible direction (a direction that, in the case of the minimization problem, leads to a reduction in the value of the objective function without violating a constraint or bound); and 3) determine the optimal point, by way of a line

search along the previously picked direction. The last two processes are iterated until the algorithm's criteria of an optimal feasible solution is satisfied. There are many kinds of methods for solving any of the above three tasks, all of which are suited to particular kinds of problems. Yet there is, generally, at least one classic example problem for each method where failure to converge on the optimal solution is inevitable.

With a knowledge of the standard form required for each of the solution algorithms, the conceptual forage allocation models may be transformed into a numerical model consistent with the appropriate standard form. This is discussed next.

3.2 Numerical Forms

The six groups of forage allocation models represent increasing degrees of complexity for expressing both the objective function and the constraints. As such, their individual numerical forms become increasingly more complicated and the less the numerical form resembles the original conceptual form. As the conceptual models are transformed into a standard form programming problem, either an L.P.P., Q.P.P. or N.L.P.P., the transformation results in changes to the structure of the objective function. The more complex the original conceptual model is the more drastic the resulting structural changes. An evaluation of these changes is the true test of the logical consistency of the model and is perhaps the most vital step in the optimization modelling process.

3.2.1 Model 1: Linear, Single-Season, Deterministic Model

The original objective function of the forage allocation model, in its linear, single-season, non-weighted, deterministic form, may be most simply expressed (without constraints) as:

$$\min f(X_j) = \min \Sigma_{i=1}^{I} (A_i - \Sigma_{j=1}^{J} X_j R_{ij})$$

or expanded as:

$$\min f(X_j) = \min \Sigma_{i=1}^{I} [HU_i (S_i + G_i)(1-L_i) - T\Sigma_{j=1}^{J} X_j C_j D_{ij})]. \qquad (2)$$

Since the entire left hand side of the function (2) or that portion representing Ai, is known and thus does not affect the gradient of the objective function, the left hand side drops out of the objective function resulting in:

$$\min \quad \Sigma_{i=1}^{I} - T\Sigma_{j=1}^{J} X_j C_j D_{ij}.$$

By definition of D_{ij}:

$$\Sigma_{i=1}^{I} D_{ij} = 1$$

since it refers to the relative contributions of each forage class i represented in the diet of herbivore j. Therefore the objective function becomes:

$$\min -T\Sigma_{j=1}^{J} X_j C_j$$

which is equivalent to:

$$\max T\Sigma_{j=1}^{J} X_j C_j \qquad (3)$$

where x is defined by a 4-dimensional Euclidean space, representing the four herbivores.

3.2.1.1 Single-Season Deterministic Constraints

The single-season deterministic constraints consist of one site maintenance constraint and five over-grazing constraints. In the standard form the site maintenance constraint becomes:

$$T\Sigma_{j=1}^{J} C_j X_j \leq H\Sigma_{i=1}^{I}((S_i+G_i)(1-L_i))-M$$

and the over-grazing constraint in standard form becomes:

$$T\Sigma_{j=1}^{J} X_j C_j D_{ij} \leq HU_i(S_i+G_i)(1-L_i) \text{ for } i=1, 2, \ldots I, \text{ where } I=5.$$

Using the data set discussed in Section 6 (Table F13) the final implemented numerical form of model 1 is:

$\min\ (2208.25,\ 1595.05,\ 485.45,\ 276.305)^T X$

subject to

$(2208.25,\ 1595.05,\ 485.45,\ 276.305)^T X \leq 7.41935 \times 10^6$

$(1457.445,\ 622.0695,\ 111.6535,\ 52.49795)^T X \leq 1.989 \times 10^6$

$(596.2275,\ 494.4655,\ 131.0715,\ 107.75895)^T X \leq 6.762 \times 10^5$

$(22.0825,\ 111.6535,\ 19.418,\ 11.0522)^T X \leq 1.9575 \times 10^5$

$(88.33,\ 175.4555,\ 72.8175,\ 96.70675)^T X \leq 1.4904 \times 10^5$

$(44.165,\ 191.406,\ 150.4895,\ 8.28915)^T X \leq 2.85085 \times 10^5.$

The above constraints are used throughout all of the single-season deterministic models.

3.2.2 Model 2: Linear, Multiple-Season, Deterministic Model

In the previous single-season model objective function (3), the only unknowns were the X's, the number of herbivores. Upon adding the aspect of seasonality, though, the S_{in}'s, or standing crops, are also unknown after the first season since they are dependent on the X's of the previous season. Thus, the multiple-season objective function is evaluated in terms of both S_{in} and X_{jn} as:

$$\min f(S_{in},X_{jn}) = \min \Sigma_{i=1}^{I} \Sigma_{n=1}^{N} (A_{in} - \Sigma_{j=1}^{J} X_{jn} R_{ijn})$$

$$<===>$$

$$\min \Sigma_{i=1}^{I} \Sigma_{n=1}^{N} (H\, U_{in}(S_{in}+G_{in})(1-L_{in}) - T_n \Sigma_{j=1}^{J} X_{jn} C_{jn} D_{ijn})) \quad (4)$$

$$X \in E^{((J+I)N-I)}$$

for $i=1, 2, \ldots I$, where $I=5$
for $j=1, 2, \ldots J$, where $J=4$
for $n=1, 2, \ldots N$, where $N=4$

The variables S_{in}'s represent the amount of biomass remaining from the previous season as found at the start of the n^{th} season. Thus, they represent a state variable. Their corresponding state equation is:

$$S_{i,n+1} = (S_{in}+G_{in})(1-L_{in}) - T_n/H \Sigma_{j=1}^{J} (X_{jn} C_{jn} D_{ijn}) \quad (5)$$

for $n=1, 2, \ldots N-1$

where all the variables representing the variable S are known with the exception of the variables X_{jn}. Therefore, the state equation for S_{in} can be expressed solely in terms of the unknown variables, X_{jn}, and the known variables, G_{in}, L_{in}, C_{jn}, D_{ijn}, and T_n where:

S_{i1} is known for all i

$$S_{i,n+1} = S_{i1} \Pi_{l=1}^{n} (1-L_{il}) + \Sigma_{m=1}^{n} G_{im} \Pi_{l=m}^{n} (1-L_{il})$$

$$- 1/H \Sigma_{m=1}^{n} (T_m (\Sigma_{j=1}^{J} X_{jm} C_{jm} D_{ijm}) \; \Pi_{l=m+1}^{n} (1-L_{il}) \quad (6)$$

for $n=1, 2, \ldots N-1$, where $N=4$.

There are several ways in which to treat the variables S_{in} in the objective function and in the constraints. One way is to treat them as forced decision variables. In this case the objective function remains as (4), which is defined by a 31 dimensional Euclidean space, and is constrained by a system of state biomass equality constraints (5), which force the values of the decision variables S_{in}. Another way would be to use expression (6) as a means of substituting the variables, S_{in} for $n>1$, out of objective function (4) and all of the constraints. As such, the state biomass system (5) drops out of the problem completely and the original 31 dimensional objective function (4), becomes a 16 dimensional objective function in the form of:

$$\min f(X_{jn}) = \min \Sigma_{i=1}^{I} \Sigma_{n=1}^{N} [HU_{in} S_{i1} \Pi_{l=1}^{n} (1-L_{il})$$

$$+ HU_{in} \Sigma_{m=1}^{n} (G_{im} \Pi_{l=m}^{n} (1-L_{il}))$$

$$- U_{in} \Sigma_{m=1}^{n-1} (T_m (\Sigma_{j=1}^{J} X_{jm} C_{jm} D_{ijm}) \Pi_{l=m+1}^{n} (1-L_{il})) \quad (7)$$

$$- T_n \Sigma_{j=1}^{J} (X_{jn} C_{jn} D_{ijn})]$$

$$X \in E^{(J \cdot N)}.$$

The latter method (7) would certainly be more efficient than the former (4) with respect to computer (CPU) time and the needed central memory space due to the greatly reduced dimensionality of the problem. In the former case, where the variables S_{in} are treated as forced decision variables (4), the problem is more than twice as large with respect to dimensionality but the computational set up is far simpler. Consequently, the former method was employed to evaluate this model. The method of substitution is later employed in Model 6, where Model 2 serves as a basis of verification, in part, for the internal consistency of the logic employed in Model 6. Recall that either method is a different representation of an algebraically identical problem.

In either expression of the objective function (4) or (7), some of the constants drop out when expressing the function in the standard form of the L.P.P. For example, the objective function, upon substitution, in the standard form is:

$$\min f(X_{jn}) = \min \Big[\Sigma_{i=1}^{I}\Sigma_{n=1}^{N}(-U_{in}\Sigma_{m=1}^{n-1}(T_m\Sigma_{j=1}^{J}(X_{jm}C_{jm}D_{ijm})\Pi_{l=m+1}^{n}(1-L_{il}))$$

$$- T_n\Sigma_{j=1}^{J}(X_{jn}C_{jn})\Big] \qquad (8)$$

$$X \in E^{16}.$$

The objective function without substitution, was used for model analysis, in standard form is:

$$\min f(S_{in},X_{jn}) = \min \Big[\Sigma_{i=1}^{I}(\Sigma_{n=2}^{N}(U_{in}S_{in}(1-L_{in})$$

$$- \Sigma_{n=1}^{N}T_n\Sigma_{j=1}^{J}(X_{jn}C_{jn}D_{ijn}))\Big] \qquad (9)$$

$$X \in E^{31}.$$

Thus, neither objective function, (8) or (9), attempts to minimize the sum of the differences between the available herbage and the grazed forage on a seasonal basis, as in the original conceptual model. Rather, they maximize the forage grazed in the first season and minimize the differences between a portion of the available herbage, that of the standing crop remaining at season n (for n=2, 3, 4), and the forage grazed.

The principal structural difference derived by the incorporation of seasonality in the model is the ability of the model to regulate the size of the standing crop after the first season. For example, the objective function can inhibit grazing in the early seasons allowing the standing crop to build up in the remaining seasons. This can only occur, of course, if it is beneficial to the optimization of the functional objective. This is clearly illustrated by the examination of the objective function in the form of (8).

There is a third simpler alternative to the two considered above (Model 2B). The first two versions of the multiple-season models, namely versions (8) and (9) of Model 2, are algebraically equivalent. Consider, then, Model 2A which is not algebraically equivalent to (8) or (9), but is almost "numerically" equivalent to (8) or (9) (i.e. differences are virtually insignificant), and which is structurally equivalent to Model 1:

$$\max f(X_{jn}) = \max \Sigma_{n=1}^{N} (T_n \Sigma_{j=1}^{J} (X_{jn} C_{jn})). \tag{10}$$

Since the objective functions of both Model 2B, (8) or (9), and Model 2A, (10), are constrained by a system of over-grazing constraints such that:

$$A_{in} - \Sigma_{j=1}^{J} X_{jn} R_{ijn} \geq 0 \text{ for all } i$$

and since the only unknown variables in A_{in} are the decision variables X_{jn}, Model 2A, (10), is virtually equivalent to Model 2B, (8) or (9). The similarity between the two models can best be illustrated by examination of their gradients, where the gradient of Model 2A is:

$$F_A = \nabla F(X_{jn}) = [-T_n C_{jn}] \quad \text{for all } j \text{ and } n \tag{11}$$

and the gradient of Model 2B is:

$$F_B = \nabla F(X_{jn}) = [-T_n C_{jn} (1 + \Sigma_{i=1}^{I} (D_{ijn} \Sigma_{m=n+1}^{N} (U_{im} \Pi_{l=n+1}^{N} (1 - L_{il}))))] \tag{12}$$

$$\text{for all } j \text{ and } n.$$

For a derivation of the gradient of Model 2B the reader is referred to Appendix V.

The two gradients, (11) and (12), differ by only a factor of:

$$\Sigma_{i=1}^{I} (D_{ijn} \Sigma_{m=n+1}^{N} (U_{im} \Pi_{l=n+1}^{N} (1 - L_{il}))) \tag{13}$$

$$\text{for } n = 1, \ldots N-1.$$

All of the variables in (13) are known and all range from zero to one. Thus, each additional term in the summation sequence of m to n is exponentially smaller than the previous one. Therefore the effect of (13) on the objective function is small and, although it could result in a different solution value vector, differences in the amount of remaining herbage or grazed forage on a seasonal basis are insignificant. An example of these differences are presented later in this chapter in section 7.1.2.

3.2.2.1 Multiple-Season Deterministic Constraints

The multiple-season constraints, as do the single-season constraints, consist of site maintenance constraints and over-grazing constraints. In addition to these, the aspect of seasonality also requires a consideration of the population dynamics of the herbivores.

There are many possible ways in which changes in animal numbers can be regulated. The simplest scheme would be to either not allow changes or to allow any degree of change in animal numbers. By not allowing changes there is little difference between it and the single-season model. In either case, though, the population dynamics of the herbivores are ignored altogether. The next step in the resolution of logic would be to allow only positive or negative changes in animal numbers, over seasons, as in the simplest pure birth and death processes. The latter was chosen for the model evaluation process and is represented by the system of "no seasonal increase" constraints which are:

$$X_{jn} \geq X_{j,n+1}$$

or in standard form, expressed as:

$$X_{j,n+1} - X_{jn} \leq 0 \qquad (14)$$

for j=1, 2,...J where J=4
for n=1, 2,...N-1 where N=4.

When the variable S_{in} is not substituted out of the objective function and the constraints, as is the case in the evaluation of the deterministic models, then it is also necessary to include the "state biomass balance equations" in the constraint set. The state biomass balance equations simply ensure that all of the herbage left over after grazing at the end of one season is fully present at the start of the next grazing season. Hence, the values of the S_{in} decision variables are forced by the state biomass balance equations. The state biomass balance equation is:

$$S_{i,n+1} = (S_{in}+G_{in})(1-L_{in})-T_n/H\Sigma_{j=1}^{J}X_{jn}C_{jn}D_{ijn}$$

for i=1, 2,...I where I=5

for n=1, 2,...N-1 where N=4.

In the standard form the biomass balance equation system is expressed as:

$$S_{i,n+1} - S_{in}(1-L_{in}) + T_n/H\Sigma_{j=1}^{J}X_{jn}C_{jn}D_{ijn} = G_{in}(1-L_{in})$$

for i=1, 2,...I where I=5

for n=2, 3,...N-1 where N=4 (15)

$$S_{i2} + T_1\Sigma_{j=1}^{J}X_{j1}C_{j1}D_{ij1} = (S_{i1}+G_{i1})(1-L_{i1})$$

for i=1, 2,...I

for n=1.

The system of over-grazing constraints and the site maintenance constraints are the same as in the single-season models. The over-grazing constraints in standard form are:

$$T_n\Sigma_{j=1}^{J}X_{jn}C_{jn}D_{ijn}-HU_{in}S_{in}(1-L_{in}) \leq HU_{in}G_{in}(1-L_{in})$$

for 1=1, 2,...I

for n=2, 3,...N (16)

$$T_1\Sigma_{j=1}^{J}X_{j1}C_{j1}D_{ij1} \leq HU_{i1}(S_{i1}+G_{i1})(1-L_{i1})$$

for i=1, 2,...I

for n=1.

A different constraint is required for the first season since S_{i1} are known for all i and thus it is not desirable to incorporate them as fixed decision variables.

The site maintenance system ensures that a specific level of biomass, M, in kilograms, remains at the end of each grazing system. In standard form the multiple-season site maintenance constraint system is:

$$T_n \Sigma_{j=1}^{J} X_{jn}C_{jn} - H\Sigma_{i=1}^{I}(S_{in}(1-L_{in})) \leq H\Sigma_{i=1}^{I}(G_{in}(1-L_{in}))-M \qquad (17)$$

for n=2, 3,...N where N=4

$$T_1\Sigma_{j=1}^{J} X_{j1}C_{j1} \leq H\Sigma_{i=1}^{I}(S_{i1}+G_{i1})(1-L_{i1}) - M$$

for n=1.

Thus, all of the multiple-season deterministic models are constrained by 12 no seasonal increase constraints, (14), 15 state biomass balance equations, (15), 20 over-grazing constraints, (16), and 4 site maintenance constraints, (17). This results in a total of 51 constraints and 31 decision variables (16 herbivore and 15 standing crop decision variables).

The final numerical forms of Model 2 are presented for both the Model 2A and the 2B versions (which differ only with the functional objective) are presented in Table F2. It should be noted, however, that upon substitution of the S_{in} variable out of the model that none of the constraints or the objective functions resemble the standard form constraints (14), (15), (16) and (17) nor that of the objective function of model 2B, (7). Nor do they resemble the numerical values of Table F2. The case of substitution is closely examined later in the discussion of Model 6 in section 3.2.6 of this chapter.

The aspect of weighting in the objective function is considered next.

3.2.3 Model 3: Linear, Single-Season, Weighted, Deterministic Model

As discussed previously in Chapter A, there are many ways in which the objective function can be weighted. Since the desired effect is to place more emphasis on the allocation of the more common plant groups the objective function is weighted by the degree of availability of the different plant groups. In simple shorthand form, the objective function is expressed as:

$$\min \Sigma_{i=1}^{I}(A_i - \Sigma_{j=1}^{J} X_j R_{ij})W_i$$

$$\text{where } W_i = A_i/H = U_i(S_i+G_i)(1-L_i)$$

$$X \in E^4.$$

The variable H is a constant, and thus has no effect on determining differences in the degrees of weighting bewteen the various plant groups. Therefore, H is dropped from the weighting term.

Table F2. Numerical form of the linear, multiple-season, non-weighted, deterministic models (Models 2A and 2B), consisting of 31 decision variables (X's and S's) and 51 constraints of which 36 are inequalities and 15 are equality constraints. The b's represent, in standard form notation, the right-hand-side values of the constraints.

	1 X_{11}	2 X_{21}	3 X_{31}	4 X_{41}	5 S_{12}	6 S_{22}	7 S_{32}	8 S_{42}	9 S_{52}	10 X_{12}	11 X_{22}	12 X_{32}	13 X_{42}	14 S_{13}	15 S_{23}	16 S_{33}	17 S_{43}	18 S_{53}	19 X_{13}	20 X_{23}	21 X_{33}	22 X_{43}	23 S_{14}	24 S_{24}	25 S_{34}	26 S_{44}	27 S_{54}	28 X_{14}	29 X_{24}	30 X_{34}	31 X_{44}	b_i
OBJECTIVE FUNCTIONS																																
Model 2A: Maximize Grazed	237.6	168.6	50.4	33						553.5	396.9	118.8	72.9						473.3	342.75	102	50.25						942.2	686	208.6	119	
Model 2B: Minimize (Available - Grazed)	-237.6	-168.6	-50.4	-33	950	2700	950	2400	950	-553.5	-396.9	-118.8	-72.9	4500	2500	2000	2000	2400	-473.3	-342.75	-102	-50.25	2100	2100	2100	2100	2100	-942.2	-686	-208.6	-119	
≤ INEQUALITY CONSTRAINTS																																
No Seasonal Increase Constraints																																
1	-1									1																						0
2		-1									1																					0
3			-1									1																				0
4				-1									1																			0
5										-1									1													0
6											-1									1												0
7												-1									1											0
8													-1									1										0
9																			-1									1				0
10																				-1									1			0
11																					-1									1		0
12																						-1									1	0
Site Maintenance Constraints																																
13	237.6	168.6	50.4	33																1												5.6598×10^6
14					-9500	-9000	-9500	-8000	-9500	553.5	396.9	118.8	72.9																			4.6843×10^6
15														-9000	-5000	-4000	-4000	-8000	473.3	342.8	102	50.25										1.5995×10^5
16																							-3000	-3000	-3000	-3000	-3000	942.2	686	208.6	119	-150
Overgrazing constraints																																
17	142.6	57.32	12.6	.99																												7.83×10^4
18	64.15	30.35	7.056	5.94																												1.9475×10^5
19	9.504	28.66	6.048	1.32																												6.75×10^4
20	21.384	47.21	13.65	24.75																												4.5×10^4
21		5.059	6.048																													4.275×10^4
22					-950					348.7	142.8	24.95	10.21																			3.42×10^5
23						-2700				149.4	103.1	26.14	18.95																			5.4×10^4
24							-950			11.07	51.6	9.504	2.916																			4.75×10^4
25								-2400		38.75	71.44	32.08	40.1																			1.2×10^4
26									-950	5.535	27.78	26.14	.729																			5.7×10^4
27														-4500					317.1	157.7	33.66	13.07										[illegible]
28															-2500				127.8	102.8	26.52	22.11										5×10^4
29																-2000			4.733	10.28	1.02	2.01										0
30																	-2000		14.2	20.57	6.12	11.06										1×10^4
31																		-2400	9.666	51.41	34.68	2.01										2.4×10^4
32																							-2100					650.1	260.7	33.43	30.56	0
33																								-2100				254.4	274.4	75.1	63.07	0
34																									-2100				6.46		4.36	0
35																										-2100		9.622	11.72	4.122	16.28	0
36																											-2100	28.27	130.2	89.7	5.95	0
EQUALITY CONSTRAINTS																																
Biomass balance constraints																																
37	142.6	57.32	12.6	.93	10,000																											2.61×10^6
38	64.15	30.35	7.056	5.94		10,000																										1.9475×10^6
39	9.504	28.66	6.048	1.32			10,000																									2.25×10^5
40	21.38	47.21	14.65	24.75				10,000																								4.5×10^5
41		5.058	6.048						10,000																							4.275×10^5
42					-9500					348.7	142.8	24.95	10.21	10,000																		3.42×10^5
43						-9000				149.4	103.1	26.14	18.95		10,000																	1.8×10^5
44							-9500			11.07	51.6	9.504	2.916			10,000																4.75×10^5
45								-8000		38.75	71.44	32.08	40.1				10,000															4×10^4
46									-9500	5.535	27.78	26.14	.729					10,000														5.7×10^5
47														-9000					317.1	157.7	33.66	13.07	10,000									0
48															-5000				127.8	102.8	26.52	22.11		10,000								1×10^5
49																-4000			4.711	10.28	1.02	2.01			10,000							0
50																	-4000		14.2	20.57	6.12	11.06				10,000						2×10^4
51																		-8000	9.666	51.41	34.68	2.01					10,000					1×10^4

All the variables in A and W, for all i, are known. Thus the entire left-hand-side of the objective function drops out in the standard form, becoming:

$$\text{MAX } [T\Sigma_{j=1}^{J}(X_j C_j(\Sigma_{i=1}^{I} HU_i(S_i+G_i)(1-L_i)\cdot D_{ij}))]. \tag{18}$$

As in Model 1, Model 3 in standard form also maximizes the degree of grazing as an L.P.P. The aspect of weighting tends to exhibit an increased selection for the herbivores that have a greater preference for those plant groups that are available in greater abundance. If this alteration in selection of herbivores results in a different selection or degree in selection, with respect to the absence of weighting, it will correspondingly result in a greater utilization of the more abundant plant groups.

The objective function of Model 3 in numerical form is expressed as:

$$(332,210.5272;\ 167,422.6846;\ 36,826.5426;\ 19,622.4779)X^T$$

and is subject to the deterministic single-season constraints formulated in section 3.2.1

Besides the aspects of seasonality and weighting, there is the quadratic case. This is considered next.

3.2.4 Model 4: Quadratic, Single-Season Non-Weighted, Deterministic Model

Just as Model 3 may be compared to Model 1 for the effect of weighting, Model 4 may be compared to Model 1 for the effect of squaring the objective function. The effect of squaring tends to smooth out the differences between the available herbage and the grazed forage between both seasons and plant groups. Since it attempts to partition the value of the objective function throughout as evenly as possible, it also gives greater emphasis to the more abundant plant groups, as in weighting. That way the degree of remaining herbage of the more abundant plant groups does not differ much from that of the less abundant plant groups. Thus, proportionally more herbage must be utilized in the more abundant plant groups, relative to less abundant ones, in order for this to be accomplished.

Model 4, a quadratic programming problem can be expressed most simply as:

$$\min f(X_j) = \min \Sigma_{i=1}^{I}(A_i - \Sigma_{j=1}^{J} X_j R_{ij})^2$$

$$X \in E^4.$$

In the single-season model, it is not necessary to substitute out the variables, S_{in}. However, if the aspect of seasonality is being considered it becomes necessary since equality constraints are not permissible in the Q.P.P. standard form model.

In expressing the objective function in standard form, the function must be decomposed into the hessian n x n matrix, Q, representing the quadratic terms and the linear terms of the "c", n x 1 vector, the method for which was discussed in section 3.1.2.

The first order partial derivatives of the objective function, representing the gradient, are:

$$\frac{\partial f}{\partial X_K} = \nabla f(X) = -2T\Sigma_{i=1}^{I}(A_i - T\Sigma_{j=1}^{J}(X_j C_j D_{ij})\cdot(C_K D_{iK}))$$

for K=1, 2,...J where J=4.

The gradient evaluated at zero, representing the linear terms of the standard form C vector, is:

$$\nabla f(X)\big|_0 = -2TH\Sigma_{i=1}^{I}(U_i(S_i+G_i)(1-L_i)\cdot C_K\cdot D_{iK}) \quad (19)$$

for K=1, 2,...J where J=4.

The second order partial derivatives of the objective function, representing the hessian matrix, Q, are:

$$\frac{\partial 2f}{\partial X_L \partial X_K} = Q(X) = 2T^2\Sigma_{i=1}^{I}(C_L D_{iL}\cdot C_K D_{iK}) \quad (20)$$

for L, K = 1, 2,...J where J=4.

Hence, the hessian, Q, is a positive definite symmetric matrix, with the diagonal terms representing the second order terms and the off-diagonal terms each representing one-half of the value of the first order product terms (1/2 value in the lower diagonal + 1/2 value in the upper diagonal = total full value).

The constraint set is equivalent to the one incorporated in Models 1 and 3. The Q.P.P. in final numerical form is derived by an M matrix, (m + n) x (m + n), consisting of the hessian, Q, and the standard form A, m x n matrix of the constraints, and the q, n vector, made up of the linear standard form c vector and standard form b vector of the constraints as follows:

$$\begin{bmatrix} Q & -A^T \\ A & O \end{bmatrix} \qquad \begin{bmatrix} c \\ -b \end{bmatrix}$$

M Matrix q vector.

Thus, a Q.P.P. algorithm requires the numerical values of the model to be supplied in the form of the above M matrix and q vector. The numerical values of the M matrix and q vector are given in Table F3.

This concludes the discussion of the numerical form of the true standard form models; those models presented in matrix form. A summary of these models is given in Table F4. The two following groups, Models 5 and 6, are set up for solution by a N.L.P.P. algorithm. Thus, the models are supplied in the form of a FORTRAN subroutine. The numerical expressions used for the evaluation of Models 5 and 6 will be discussed next. In Section 4, the actual coding is presented.

Table F3. Numerical form of the quadratic, single-season non-weighted, deterministic models Q, A, and M matrices, and the c, b, and q vectors of the standard form Q.P.P.

Q matrix (A symmetric matrix, however only the lower diagonal is shown here)

$$
\begin{bmatrix}
4{,}979{,}747.065 & & & \\
2{,}455{,}726.06 & 1{,}422{,}707.974 & & \\
508{,}768.8092 & 356{,}030.9669 & 115{,}945.5576 & \\
299{,}827.9637 & 211{,}457.5953 & 56{,}979.385 & 47{,}822.16537
\end{bmatrix}
$$

A matrix

$$
\begin{bmatrix}
-2{,}208.25 & -1{,}595.05 & -485.45 & -276.305 \\
-1{,}457.445 & -622.0695 & -111.6535 & -52.49795 \\
-596.2275 & -494.4655 & -131.0715 & -107.75895 \\
-22.0825 & -111.6535 & -19.418 & -11.0522 \\
-88.33 & -175.4555 & -72.8175 & -96.70675 \\
-44.165 & -191.406 & -150.4895 & -8.28915
\end{bmatrix}
$$

C vector

$$
\begin{bmatrix}
-6.6641 \times 10^9 \\
-3.3485 \times 10^9 \\
-7.3653 \times 10^8 \\
-3.9245 \times 10^8
\end{bmatrix}
$$

-b vector

$$
\begin{bmatrix}
7.37335 \times 10^6 \\
1.989 \times 10^6 \\
6.762 \times 10^5 \\
1.9575 \times 10^5 \\
1.4904 \times 10^5 \\
2.68065 \times 10^5
\end{bmatrix}
$$

M matrix

$$
\begin{bmatrix}
Q & -A^T \\
A & 0
\end{bmatrix}
$$

q vector

$$
\begin{bmatrix}
c \\
-b
\end{bmatrix}
$$

Table F4. Summary of deterministic model formulations and deterministic constraints. The general formula for the objective functions is in conceptual form. The constraints are in standard form.

Objective Functions

MODEL		MODEL DESCRIPTION			CONSTRAINTS
1:	Linear	(Exponent=1), Single-season	(N=1), Non-weighted	(W_{in}=1)	I, IV, V
2:	Linear	(Exponent=1), Multiple-season	(N=4), Non-weighted	(W_{in}=1)	I, II, III, IV, V
3:	Linear	(Exponent=1), Single-season	(N=1), Weighted	(W_{in}=weight function)	I, IV, V
4:	Quadratic	(Exponent=2), Single-season	(N=1), Non-weighted	(W_{in}=1)	I, IV, V

Shorthand Formula

$$\text{MINIMIZE} \quad [\Sigma_{i=1}^{I}\Sigma_{n=1}^{N}[A_{in}-\Sigma_{j=1}^{J} X_{jn}R_{ijn})^{\text{EXPONENT}}.W_{in}]$$

Expanded Formula

$$\text{MINIMIZE} \quad [\Sigma_{i=1}^{I}\Sigma_{n=1}^{N}(HU_{in}(S_{in}+G_{in})(1-L_{in})-T_n\Sigma_{j=1}^{J}X_{jn}C_{jn}D_{ijn})^{\text{EXPONENT}}.W_{in}]$$

where $W_{in} = A_{in}$

Deterministic Constraints

	Constraint	Description
I	$B_{jn} \leq X_{jn} \leq Z_{jn}$	Reasonable stocking limit (2·J·N) constraints possible)
II	$X_{jn+1}-X_{jn} \leq 0$	No seasonal increase in herbivores (J·(N-1) constraints)
III	$S_{i(n+1)}-S_{in}(1-L_{in})+T_n\Sigma_{j=1}^{J}X_{jn}C_{jn}D_{ijn} = G_{in}(1-L_{in})$	Biomass balance equation: Remaining standing crop of last season is fully realized in next season (I·(N-1) constraints)
IV	$T_n\Sigma_{j=1}^{J}X_{jn}C_{jn}-H\Sigma_{i=1}^{I}(S_{in}(1-L_{in})) \leq H\,\Sigma_{i=1}^{I}(G_{in}(1-L_{in}))-M$	Site maintenance constraint (N constraints)
V	$T_n\Sigma_{j=1}^{J}X_{jn}C_{jn}D_{ijn}-HU_{in}S_{in}(1-L_{in}) \leq HU_{in}G_{in}(1-L_{in})$ for n=2,3,4	Overgrazing constraint (I·N constraints)
	$T_n\,\Sigma_{j=1}^{J}X_{jn}C_{jn}D_{ijn} \leq HU_{in}(S_{in}+G_{in})(1-L_{in})$ for n=1	

3.2.5 Model 5: The Single-Season, Stochastic Models

Model 5 actually refers to a group of models which are the stochastic versions of the deterministic Models 1, 3, and 4. Model 5A, the linear, non-weighted model, Model 5B, the linear, weighted model, and Model 5C, the quadratic, non-weighted model, may be directly compared to the deterministic, standard form models; models 1, 3 and 4 respectively.

Stochasticity, as used herein, refers to the use of chance-constraints (Charnes and Cooper 1959, 1962, 1963; Kirby 1970). The variables G and C throughout, and S only at n=1 are considered to be normally distributed, as discussed previously in section 2. By the use of chance constraints one can a priori set a confidence level on the probability that the constraints, a posteriori, will be satisfied. The objective function, however, remains the same as in the deterministic model. For example, Model 5A is made up of a linear, single-season, objective function and is constrained by quadratic constraints. As such, it requires an N.L.P.P. algorithm to solve Model 5A.

The objective function of Model 5A is:

$$\text{MAX } T\Sigma_{j=1}^{J} X_j C_j . \tag{21}$$

The function (21) is identical to that of Model 1, which was derived above.

As in the deterministic version of Model 5, the equivalent of Model 1, the model is subject to over-grazing and site maintenance constraints. However, in Model 5, the randomness of the variables S, G, and C is considered through the application of chance constraints. Thus, the site maintenance constraints of Model 1, in its chance constraint form, may be expressed as:

$$\begin{gathered} \Sigma_{j=1}^{J}(TX_jC_j+k_c((TX_j)^2\cdot VAR[C_j])^{1/2}) \\ \leq \\ \Sigma_{i=1}^{I}(H(S_i+G_i)(1-L_i)-k_s((H(1-L_i))^2\cdot VAR[S_i])^{1/2} \\ -\ k_g((H(1-L_i))^2\cdot VAR[G_i])^{1/2})\ -\ M \\ 1 \text{ constraint} \end{gathered} \tag{22}$$

where VAR refers to the variance operator and k_c, k_s and k_g are standard normal deviates which represent the fractile of probability that the constraint will be a posteriori satisfied on the rangeland. (See Appendix V).

The chance-constraint form of the deterministic over-grazing constraints of Model 1 is expressed as:

$$\Sigma_{j=1}^{J} TX_jC_jD_{ij}+k_c((TX_jD_{ij})^2\cdot VAR[C_j])^{1/2})$$

$$\leq \tag{23}$$

$$HU_i(S_i+G_i)(1-L_i)-k_s((HU_i(1-L_i))^2VAR[S_i])^{1/2}$$
$$-\ k_g((HU_i(1-L_i))^2\cdot VAR[G_i])^{1/2}$$
$$\text{for } i=1,\ 2,\ldots I \quad \text{where } I=5.$$

Thus, Model 5 is constrained by a total of 6 chance-constraints, consisting of 1 site maintenance and 5 over-grazing constraints. The level of confidence ensuring that the constraints are satisfied is limited by the degree of variance in the random variables S, G, and C. The upper bound on the degree of confidence is established just before the point in which the right-hand side of any chance constraint becomes negative. These right-hand side values must be determined a priori to the computer runs of the model by a separate program or through hand calculations, since they are supplied as an upper or lower bound in the case of an inequality constraint, and a constant in the case of an equality constraint. The models were evaluated up to and including the 99% level of satisficing the constraints. The right-hand side values were determined by a computer program, discussed in section 4.

In Models 5B and 5C it is not necessary to code the objective functions in the exact standard form used in Models 3 and 4, respectively, i.e., where only the variables that effect the gradient of the objective function are allowed to remain. The original conceptual forms can be supplied instead since the N.L.P.P. algorithm approximates the gradient of the coded objective function and since the internal logical consistency of the gradient so derived by the N.L.P.P. has been validated through an evaluation of the deterministic standard form models. As a cross-check verification of the actual structure of the program, the stochastic model may be run with all of the fractile levels set to zero, yielding the deterministic solution values.

The objective function used in Model 5B, the linear, weighted model, is:

$$\min f(X_j) = \min T\Sigma_{j=1}^{J}\Sigma_{i=1}^{I}(X_jC_jD_{ij})(HU_i(S_i+G_i)(1-L_i)) \tag{24}$$

and the objective function of Model 5C, the quadratic, non-weighted model, is:

$$\min f(X_j) = \min \Sigma_{i=1}^{I}[(HU_i(S_i+G_i)(1-L_i)-T\Sigma_{j=1}^{J}(X_jC_jD_{ij}))^2$$
$$\cdot HU_i(S_i+G_i)(1-L_i)]. \tag{25}$$

Model 5A represents the simplest forage allocation model in the form of a deterministic equivalent of a stochastic model, through the use of chance constraints. Models 5B and 5C represent increasing degree of complexity, yet it is not until the aspect of seasonality is considered that the models become very complex. The Model 6 series which represents the multiple-season stochastic models, are discussed next.

3.2.6 Model 6: The Multiple-Season, Stochastic Models

Model 6 refers to a group of models similar to Model 5. Model 6A, the linear, multiple-season model, is the stochastic version of the deterministic Model 2. Model 6B, the quadratic, non-weighted model, and Model 6C, the non-linear, weighted model, are stochastic models without a deterministic

standard form model counterpart. Model 6B can be evaluated by a Q.P.P. algorithm for deterministic solutions. However, Model 6C can not since it is non-linear.

In the Model 6 group, the variables G and C are considered to be normally distributed as in the single-season models. The variable S, however, is considered to be normally distributed in the first season only (n=1). Therefore, the variable S, for n=2, 3,...N, can be treated as a forced decision variable, as in Model 2, or it can be substituted out of the objective function and constraints by using expression (6). However, optimization theory does not allow for the consideration of distributed decision variables and since, after the first season, S is defined as the product and sum of the other random variables (S in the first season, G and C subsequently), it is itself defined as a random variable. Therefore it must be substituted out of the objective functions and the system of constraints. The state biomass equation system drops out completely leaving the no-seasonal increase constraints, which are unchanged from the deterministic multiple-season model, the over-grazing constraints, and the site maintenance constraints.

The objective functions of Model 6 can be expressed as:

$$\min f(X_{jk}) = \min \Sigma_{i=1}^{I}\Sigma_{n=1}^{N}((A_{in} - \Sigma_{j=1}^{J} X_{jn}R_{ijn})^{Exp} \cdot W_{in}) \tag{26}$$

where

$$A_{in} = HU_{in}(S_{in}+G_{in})(1-L_{in})$$

$$R_{ijn} = T_n C_{jn} D_{ijn}$$

$$W_{in} = \begin{cases} 1 & : \text{ Model 6A, 6B} \\ A_{in} & : \text{ Model 6C} \end{cases}$$

$$Exp = \begin{cases} 1 : & \text{Model 6A} \\ 2 : & \text{Model 6B, 6C.} \end{cases}$$

The differences in the models (26) are in the weighting function, W_{in}, and the exponent, Exp. As discussed in section 3.2.5, since the N.L.P.P. approximates the value of the gradient through the use of a numerical analysis technique (forward differencing), the superfluous parts of the conceptual objective function, with respect to the standard form, (26), need not be removed. Taking advantage of this, the objective function is left in its far simpler conceptual form, with the necessary exception of substituting out the variable S for n > 1, so as to avoid the chance of dealing with errors. The actual substitution of S is accomplished by a FORTRAN FUNCTION S. This allows the objective function to be coded in the form of (26), with calls to the FORTRAN function for substituting in the value of S. This latter, for example, yields the algebraic equivalent of the standard form (6), in the case of Model 6A.

The site-maintenance constraint system, consisting of 4 constraints, in the multiple-season, chance-constraint form is expressed as:

$$
\begin{aligned}
&\sum_{i=1}^{I}\sum_{j=1}^{J} GRAZED_{ijn} \leq \sum_{i=1}^{I} AVAILABLE_{in} - M_n \\
&\qquad\qquad\qquad\Longleftrightarrow \\
&\sum_{i=1}^{I}\Big(\sum_{m=1}^{n}\big(T_m \sum_{j=1}^{J}(X_{jm}C_{jm}D_{ijm})\Pi_{l=m+1}^{n}(1-L_{il})\big) \\
&+ \sum_{m=1}^{n}\sum_{j=1}^{J}\big(k_c((T_m X_{jm} D_{ijm}\Pi_{l=m+1}^{n}(1-L_{il}))^2 \cdot VAR[C_{jm}])^{1/2}\big)\Big) \\
&\qquad\qquad\qquad\geq \qquad\qquad\qquad\qquad\qquad\qquad (27) \\
&\sum_{i=1}^{I}\Big(HS_{i1}\Pi_{l=1}^{n}(1-L_{il}) + H\sum_{m=1}^{n} G_{im}\Pi_{l=m}^{n}(1-L_{il}) \\
&- k_s((H\Pi_{l=1}^{n}(1-L_{il}))^2 \cdot VAR[S_{i1}])^{1/2} \\
&- \sum_{m=1}^{n}\big(k_g((H\Pi_{l=m}^{n}(1-L_{il}))^2 \cdot VAR[G_{im}])^{1/2}\big)\Big) \\
&- M_n
\end{aligned}
$$

for $n=1, 2, \ldots N$, where $N=4$.

Note that with respect to notation, in the above equation (27), that:

$$\sum_{m=1}^{n} X_m \Pi_{l=m+1}^{n} Y_l \Longleftrightarrow \sum_{m=1}^{n-1} X_m \Pi_{l=m+1}^{n} Y_l + X_n.$$

The over-grazing constraint system, consisting of 20 constraints, in the multiple-season chance-constraint form is expressed as:

$$
\begin{aligned}
&\sum_{j=1}^{J} GRAZED_{ijn} \leq AVAILABLE_{in} \\
&\qquad\qquad\qquad\Longleftrightarrow \\
&T_n \sum_{j=1}^{J} X_{jn}C_{jn}D_{ijn} \\
&+ U_{in}\sum_{m=1}^{n-1}\big(T_m \sum_{j=1}^{J}(X_{jm}C_{jm}D_{ijm})\Pi_{l=m+1}^{n}(1-L_{il})\big) \\
&+ \sum_{j=1}^{J} k_c((T_n X_{jn} D_{ijn})^2 \cdot VAR[C_{jn}])^{1/2} \\
&+ \sum_{m=1}^{n-1}\sum_{j=1}^{J}\big(k_c((T_m X_{jm} D_{ijm} U_{in}\Pi_{l=m+1}^{n}(1-L_{il}))^2 \cdot VAR\ [C_{jm}])^{1/2}\big) \\
&\qquad\qquad\qquad\leq \qquad\qquad\qquad\qquad\qquad\qquad (28) \\
&HU_{in}S_{i1}\Pi_{l=1}^{n}(1-L_{il}) + HU_{in}\sum_{m=1}^{n}(G_{im}\Pi_{l=m}^{n}(1-L_{il})) \\
&- k_s((HU_{in}\Pi_{l=1}^{n}(1-L_{il}))^2 \cdot VAR[S_{i1}])^{1/2} \\
&- \sum_{m=1}^{n}\big(k_g((HU_{in}\Pi_{l=m}^{n}(1-L_{il}))^2 \cdot VAR[G_{im}])^{1/2}\big)
\end{aligned}
$$

for $i=1,2,\ldots I$, where $I=5$

for $n=1, 2, \ldots N$, where $N=4$.

Thus, the objective function (26) is subject to 24 chance constraints consisting of 20 over-grazing constraints (28) and 4 site maintenance constraints (27). In the chance-constraints, the K values k_s, k_g and k_c,

refer to standard normal deviates selected from a statistical "Z" table at the appropriate level of confidence for satisfying the constraints. In addition, it is constrained by 12 no-seasonal increase constraints, which are equivalent to those of Model 2 (14). Also, lower bounds are placed on the decision variables so that they may not become negative. Although upper bounds were not placed on the decision variables in the evaluation of the models, they may be easily imposed, as can non-zero lower bounds, for the purposes of a management scenario, for one or all of the herbivore species. A summary of the stochastic model formulation is given in Table F5.

As in Model 5, the right-hand side values of the constraints were determined, a priori, by a computer program. Model 6 was evaluated at 7 different levels of confidence, up to and including the 95% probability level of satisficing the constraints. The 99% level, used in Model 5, was too high for Model 6, due to the increased complexity of the variance structure in the multiple-season chance-constraints.

4. USER SUPPLIED COMPUTER CODES

The Non-Linear Programming Problem (N.L.P.P.) class of algorithms sometimes require the user to supply a FORTRAN subroutine which evaluates the constraints and objective functions for any given set of decision variables. For our study, a FORTRAN program was written and implemented to supply the necessary data values for the operation of the N.L.P.P. algorithm we used. The data values represent, for the most part, the right-hand side values of the constraints and the tolerance specifications to be used by the algorithm.

All of the Model 5 and Model 6 series utilize the same right-hand side values for each respective fractile of the chance-constraints and each respective model series. Our user supplied subroutine, GCOMP, used for evaluating the constraints and objective function is the same throughout the respective model series except for the obvious exception of the objective functions.

Examples of subroutine GCOMP for single-season models, using Model 5A1's version and for the multiple-season models, and using Model 6A1's version, are given in Appendix V. In addition, the program for evaluating the right-hand-side values for both the single-season series, RHS5 and the multiple-season series, RHS6, are given, in the Appendix V.

In addition to using the computer program GRG to evaluate the stochastic models, GRG served a needed purpose in evaluating the other models as well through its ability to easily incorporate the additional output functions which eliminated the need for additional computations for model analysis. A description of these functions is given in Table F6.

Table F5. Summary of stochastic model formulations and chance constraints. The general formula for the objective function is in conceptual form. The chance-constraints are in standard form. S is substituted out of the chance-constraints, as discussed later.

Objective Functions

MODEL		MODEL DESCRIPTION				CONSTRAINTS
5A:	Linear	(Exponent=1),	Single-season	(N=1),	Non-weighted ($W_{in}=1$)	I, IVB, VB
5B:	Linear	(Exponent=1),	Single-season	(N=1),	Weighted (W_{in}=weight function)	I, IVB, VB
5C:	Quadratic	(Exponent=2),	Single-season	(N=1),	Non-weighted ($W_{in}=1$)	I, IVB, VB
6A:	Linear	(Exponent=1),	Multiple-season	(N=4),	Non-weighted ($W_{in}=1$)	I, II, IVB, VB
6B:	Quadratic	(Exponent=2),	Multiple-season	(N=4),	Non-weighted ($W_{in}=1$)	I, II, IVB, VB
6C:	Non-linear	(Exponent=2),	Multiple-season	(N=4),	Weighted (W_{in}=weight function)	I, II, IVB, VB

Shorthand Formula

MINIMIZE $\left[\sum_{i=1}^{I}\sum_{n=1}^{N}\left(A_{in}-\sum_{j=1}^{J}X_{jn}R_{ijn}\right)^{EXPONENT}\cdot W_{in}\right]$

Longhand Formula

MINIMIZE $\left[\sum_{i=1}^{I}\sum_{n=1}^{N}\left(HU_{in}(S_{in}+G_{in})(1-L_{in})-T_n\sum_{j=1}^{J}X_{jn}C_{jn}D_{ijn}\right)^{EXPONENT}\cdot W_{in}\right]$

where $W_{in} = A_{in}$

Chance Constraints

IVB

$$\sum_{i=1}^{I}\sum_{m}^{n}\left(T_m\sum_{j=1}^{J}(X_{jm}C_{jm}D_{ijm})\Pi_{l=m+1}^{n}(1-L_{il})\right)$$

$$+\sum_{m=1}^{n}\sum_{j=1}^{J}\left(k_c\left((T_mX_{jm}D_{ijm}\Pi_{l=m+1}^{n}(1-L_{il}))^2\cdot VAR[C_{jm}]\right)^{1/2}\right) \le$$

$$\sum_{i=1}^{I}\left(HS_{i1}\Pi_{l=1}^{n}(1-L_{il})+H\sum_{m=1}^{n}G_{im}\Pi_{l=m}^{n}(1-L_{il})\right)$$

$$-k_s\left((H\Pi_{l=1}^{n}(1-L_{il}))^2\cdot VAR[S_{il}]\right)^{1/2}$$

$$-\sum_{m=1}^{n}\left(k_g\left((H\Pi_{l=m}^{n}(1-L_{il}))^2\cdot VAR[G_{im}]\right)^{1/2}\right)-M$$

VB

$$T_n\sum_{j=1}^{J}X_{jn}C_{jn}D_{ijn}+U_{in}\sum_{m=1}^{n-1}\left(T_m\sum_{j=1}^{J}(X_{jm}C_{jm}D_{ijm}\Pi_{l=m+1}^{n}(1-L_{il}))\right)$$

$$+\sum_{j=1}^{J}k_c\left((T_nX_{jn}D_{ijn})^2\cdot VAR[C_{jn}]\right)^{1/2}$$

$$+\sum_{m=1}^{n-1}\sum_{j=1}^{J}\left(k_c\left((T_mX_{jm}D_{ijm}U_{in}\Pi_{l=m+1}^{n}(1-L_{il}))^2\cdot VAR[C_{jm}]\right)^{1/2}\right) \le$$

$$HU_{in}S_{i1}\Pi_{l=1}^{n}(1-L_{il})+HU_{in}\sum_{m=1}^{n}\left(G_{im}\Pi_{l=m}^{n}(1-L_{il})\right)$$

$$-k_s\left((HU_{in}\Pi_{l=1}^{n}(1-L_{il}))^2\cdot VAR[S_{il}]\right)^{1/2}$$

$$-\sum_{m=1}^{n}k_g\left((HU_{in}\Pi_{l=m}^{n}(1-L_{ie}))^2\cdot VAR[G_{im}]\right)^{1/2}$$

Table F6. Output functions incorporated in the GRG user-supplied subroutine GCOMP to facilitate evaluation of the proposed single season models.

Output code	Description
WSG%	percentage of the available herbage that are warm-season grasses
CSG%	percentage of the available herbage that are cool-season grasses
WSF%	percentage of the available herbage that are warm-season forbs
CSF%	percentage of the available herbage that are cool-season forbs
SHRB%	percentage of the available herbage that are shrubs
T. AVAIL	total available herbage in kg
DIET WSG	percentage of the grazed forage that are warm-season grasses
DIET CSG	percentage of the grazed forage that are cool-season grasses
DIET WSF	percentage of the grazed forage that are warm-season forbs
DIET CSF	percentage of the grazed forage that are cool-season forbs
DIET SHR	percentage of the grazed forage that are shrubs
T GRAZED	total grazed forage in kg
CAT GRZ%	the percentage of grazed forage utilized by cattle
BIS GRZ%	the percentage of grazed forage utilized by bison
SHP GRZ%	the percentage of grazed forage utilized by sheep
ANT BRZ%	the percentage of grazed forage utilized by pronghorn antelope
TOT. AUE	total allocation of objective function in animal unit equivalents

5. INFORMATION REQUIREMENTS

In this section we discuss the kinds of information required in optimization model formulation and a comment is made on the quantity and quality of such data.

The optimization framework we have presented allows for specifying the minimum and the maximum number of animals of each species (if such bounds are to be considered in each area). Required information is the hectares or acres in the grazing area. Furthermore, the days or amount of time in each of the periods of the year must be specified. These factors are relatively well known by the resource manager for any particular area. In fact, specification of the maximum number of animals is somewhat superfluous because constraints on forage use usually prescribe the maximum. The minimum number of animals, in some cases, may be constrained by policy rather than by biology. For example, there are implicit requirements to maintain herds of feral horses in some regions of the country. These may or may not be maintained at a "biological optimum".

The amount of land area generally is well known in total hectares or acres but the amount available for grazing may be less well known. It may be possible simply to reduce the number of hectares or acres in any given area to show the actual area used by domestic or wild animals. In some instances wild animals move over large areas and long distances from season to season. Thus, their numbers may be constrained in the models by a low maximum for a particular season for a particular area or else the actual acreage may be subscripted so that it is applied differently for different animal species.

It is important to know the amount of available herbage. This, as has been noted, is a function of the initial standing crop, the growth during a given period, the loss during a given period, and the grazing regime. It has been assumed that (given the allowable use constraints for each plant species or group have been met) the plant growth will not be influenced by grazing. Furthermore, a long-term average plant growth for a given area has been assumed. This is open to question. It is known that growth varies widely from year to year due to climatic variations. This can, in part, be accounted for in the stochastic approach where growth is known but with uncertainty. However, one still needs to understand the changes in species composition from year to year and more field data need to be summarized and analyzed. In such analyses one needs to know the correlations of individual plant species or groups (one to another) in their yield relationship as climate fluctuates. This requires the use of long-term data from specific sites of plant species or plant group composition rather than simply total herbage yield. Therefore, an administrative study or researchable problem is to compile and organize and analyze such information from extant reports and files. Resource management agencies should also be encouraged to set up at selected places long-term measurement studies to accumulate such information. A one-time forage inventory does not provide that information. It simply provides the amount of herbage standing at the time of the inventory and reflects the current (or at most, a few years preceding it) the climatic conditions and grazing management present. Even then, there needs to be a valid method of adjusting or correcting a given year's forage production to the long-term climatic mean.

Less is known about the loss rates of vegetation production than is known about the accumulation rates. If an area is not grazed one does not know well the degree and timing during which vegetation is lost. Losses are due to shattering and weathering if grazing animals are not present and due to forage consumption and to trampling in addition if they are present.

Each of the above questions needs to be answered individually to provide more valid information for optimal forage allocation models. Resource management agencies need to fund work to summarize, synthesize, and evaluate such information for decision-making purposes.

Forage growth rate and loss rate information are required. Again, there is a relatively large body of information on how to calculate growth of grazingland plants but less on how to calculate loss.

A major vegetation loss comes through forage consumption. At least, this is a factor that can be controlled by man. In detailed work, however, one finds that only a relatively small part of the total vegetation that disappears in a given year is taken by the grazing herbivore as actual forage consumption. Some of the old "rules-of-thumb" suggest that 50% "utilization" is a proper level. This is expressed in the adage "take half and leave half and the half left becomes larger." Studies on the shortgrass prairie where detailed measurements were made of production and consumption show, however, that even under heavy grazing, only 25% of the forage produced would be taken as forage consumption. The rest is lost in trampling, natural weathering, or is carried over to the next year as standing dead.

The models presented herein incorporate the concept of "allowable use" factors. Generally, these vary from 30 to 50%. However, in light of recent detailed studies (noted above such that 25% seems to be an upper limit of grazing) then the utilization figures drawn from the literature and used in the models represent total disappearance not actual consumption. Still, there needs to be a thorough search of available scientific information to determine what are the allowable use factors for different plant species or groups and how do they vary from year to year subject to different climatic conditions.

The amount of forage actually consumed by grazing animals is known relatively well. Such information has been summarized by Chapter C. The importance, however, is that resource management agencies may be using figures far in excess of the actual forage intake as a forage consumption figure; they probably are including some of the trampling or wastage loss that takes place in the grazing process. Generally, most large herbivores on our western rangelands consume in the order of 2.5% of their body weight per day in oven dry forage (Van Dyne et al. 1980). Thus, a 454 kg cow (1000 lbs.) consumes about 11 kg oven dry herbage per day (about 25 lb.). This would appear to be a maximum under range grazing conditions based on the data from scientific studies. This results in a maximum of about 340 kg (or 750 lb.) per animal unit per month. Any figures higher than this definitely include more than actual consumption and include some trampling losses. Again, however, we have not summarized nor are we aware of any detailed review and analysis of available data on trampling losses.

The key problem regarding data and information in the optimization modelling framework is knowing the dietary botanical composition on any given range area in any given season by a particular herbivore species. There is a lack of good understanding of the mechanism for diet selection or large herbivores (Van Dyne et al. 1980). This is an important research and information need. For optimization modelling analyses the dietary preference concept has been used. This is treated in Chapter E. Diet preference information can be obtained from research studies but they represent only selected points in time and space. Resource management agencies may include collection of fecal material in field surveys for subsequent microscopic analysis to determine botanical composition. However, there are many problems in converting information from microscopic analysis of fecal samples to diet composition and, hence, to diet preference. It has been shown how proper use factors can be used to estimate diet composition if one knows the range herbage composition. However, proper use factors have been compiled and used for many years without adequate scientific justification of the values used. This emphasizes the need for further research and information on botanical composition of the diets of large herbivores on western grazinglands. Methodological studies are needed along with the accumulation of a larger body of knowledge of not only dietary botanical composition but also at the same time range herbage composition.

Lacking such information one may calculate a rough estimate of dietary botanical composition from known range herbage composition and proper use factor (PUF) values. This approach is described in Chapter B.

There are two provisos that should be considered when calculating dietary botanical composition from range composition and proper use factors. The first is that the rangeland under consideration be managed properly. If the land is being mismanaged the PUF values do not apply and the calculations are meaningless. The second proviso is the understanding that the efficient use of a range may require that highly palatable plants, present sometimes in small percentages, be overused in order that the more abundant but less palatable species be used up to the PUF value assigned to them. Furthermore, the method assumes the composition of the range and the proper use factors are known without error.

6. MULTI-SPECIES--MULTI-SEASON DATA SET FOR FORAGE ALLOCATION MODEL COMPARISONS

For comparison of the above models a common data set was utilized. It is based on studies on the shortgrass prairie with four large herbivore species specifically cattle, bison, sheep and pronghorn antelope (Kaute and Van Dyne 1978). The animal species were assumed to be yearling animals. Seasons of the year were assumed to be spring, summer, fall, and winter. Plants groups in the diet were warm-season grasses, cool-season grasses and grasslike, warm-season forbs, cool-season forbs, and shrubs.

The definition of the appropriate values, according to the order of terms listed in the Appendix V, for the case-study are given next.

6.1 Estimates of Mean Values.

Values are given here for U, S, G, and L corresponding to the plant data; C for the animal data; and D for the plant-animal data. Also given are the parameters H and T, and all indices as well.

The initial available herbage on the range for five plant groups is as follows:

$$S_{i1} = \begin{array}{cc} i & S_{i1}\ \text{kg ha}^{-1} \\ 1 & 50 \\ 2 & 5 \\ 3 & 5 \\ 4 & 5 \\ 5 & 15. \end{array}$$

These values assume heavy use prior to the first determination. The values for the first season are for spring. Approximately one-third of the material is carried over and thus two-thirds grazed during the winter.

The model structure also requires the kilograms of forage required per animal per day by animal species and the season of the year. These values are given in Table F7.

The values are based on the estimated weights of the animals in each season, given in kilograms of live body weight. To these are applied percentages of forage intake expected at that season to derive the kilograms of forage required per animal per day. Growth rates of the animals are assumed to be more-or-less steady throughout the year. Thus, cattle gain from 180 to 340 kg from spring through the following winter, bison from 165 to 320 kg, sheep from 37.5 to 75 kg, and pronghorn from 26.25 to 45 kg.

Forage consumption, given as a percent of body weight, varies from a low of 1.53% for bison during the winter months to a high of 2.64% for sheep and cattle during the summer months. The general assumption is that winter values for forage intake are about 20% below the mean and summer values 20% above the mean. Spring and fall values are assumed to fall on the mean. The overall

Table F7. Base data for examining the proposed forage allocation models: Consumption rates per animal per day by animal species and season of the year.

Animal Species	C_{jk} Season n=1 Spring wt	%	kg	n=2 Summer wt	%	kg	n=3 Fall wt	%	kg	n=4 Winter wt	%	kg
Cattle	180	2.2	3.96	233	2.64	6.15	287	2.2	6.31	340	1.98	6.73
Bison	165	1.7	2.81	216	2.04	4.41	269	1.7	4.57	320	1.53	4.90
Sheep	38	2.2	0.84	50	2.64	1.32	62	2.2	1.36	75	1.98	1.49
Pronghorn	26	2.1	0.55	32	2.52	0.81	32	2.1	0.67	45	1.89	0.85

mean values, yearlong, of 2.2, 1.7, 2.2, and 2.1% are based on the information in Chapter C.

Four seasons of the year, T_n, with variable duration are utilized. These are as follows:

1	=	15 Apr. - 15 June	=	Spring	=	60	
2		15 June - 15 Sept.		Summer		90	days
3		15 Sept. - 1 Dec.		Fall		75	
4		1 Dec. - 15 Apr.		Winter		140	

During the spring interval there is major cool-season plant growth. During the summer interval there is major warm-season plant growth. The fall interval is characterized by extant mature plant material. The winter period is characterized by mature plant material which has been leached and weathered. Note that the seasonal intervals are of unequal length.

Dietary composition and preference indices were assumed to be equivalent to each other. The values are based on data of Kautz and Van Dyne (1978) given in Table F8.

It is assumed that non-reproductive animals are used throughout. For example, they start as yearling animals and do not reproduce during the interval of the optimization analysis. The maximum number of animals is set to be unbounded in these initial runs.

For multiple-season runs, plant growth is required. Estimates are derived from field data from shortgrass prairie grazingland studies (Van Dyne unpublished). The values are given in Table F9. Note the warm-season grasses grow both in the spring and summer but with major growth in the summer. Cool-season grasses grow in the spring with only minor growth in the summer and fall. Warm-season forbs grow both in spring and summer but with major growth in the summer. Cool-season forbs grow primarily in the spring with minor growth in the summer and fall. Shrub growth occurs in the spring, summer, and fall but with major growth in the summer. No plant category shows any appreciable growth during the winter interval.

In formulating our optimization problem we assumed an area (H) of 10,000 hectares (24,700 acres).

The index for plant growth, for plant groups i, is from 1 through 5 (I) respectively as follows: warm-season grasses, cool-season grasses, warm-season forbs, cool-season forbs, and shrubs. The category cool-season grasses includes grasslike plants such as the dryland sedges.

The index for herbivores, j, is from 1 through 4 (J) and represents cattle, bison, sheep, and pronghorn antelope, respectively.

The index for seasons, n, goes from 1 through 4 (N) and represents spring, summer, fall, and winter. But the periods are of unequal length.

Table F8. Base data for examining the proposed forage allocation models: Dietary botanical composition, in proportions, are used as preference indices.

Plant Group (i)	Herbivore (j)	D_{ijk} in proportion — Seasonal Period (n): Spring	Summer	Fall	Winter
Warm-season grasses	Bison	.60	.63	.67	.69
	Cattle	.34	.36	.46	.38
	Sheep	.25	.21	.33	.19
	Pronghorn	.03	.14	.26	.26
Cool-season grasses	Bison	.27	.27	.27	.27
	Cattle	.18	.26	.30	.40
	Sheep	.14	.22	.26	.36
	Pronghorn	.18	.26	.44	.53
Warm-season forbs	Bison	.04	.02	.01	.00
	Cattle	.17	.13	.03	.01
	Sheep	.12	.08	.01	.00
	Pronghorn	.04	.04	.04	.04
Cool-season forbs	Bison	.09	.07	.03	.01
	Cattle	.28	.18	.06	.02
	Sheep	.37	.27	.06	.02
	Pronghorn	.75	.55	.22	.12
Shrubs	Bison	.0	.01	.02	.03
	Cattle	.03	.07	.15	.19
	Sheep	.12	.22	.34	.43
	Pronghorn	.00	.01	.04	.05

Table F9. Base data for examining the proposed forage allocation models: Plant growth in kilograms per hectare for five plant groups over four grazing seasons.

Plant Group	G_{ik} in kg/ha per season Spring	Summer	Fall	Winter
Warm-season grasses	240	360	0	0
Cool-season grasses	200	20	20	0
Warm-season forbs	20	50	0	0
Cool-season forbs	45	5	5	0
Shrubs	30	60	10	0

During each season there is some loss of forage, whether or not it is grazed. This applies both to the carryover vegetation from the preceding season as well as the growth during the current season. Averaged over all forage plants there is about 5% loss in the spring, 10% in the summer, 50% in the fall, and a greater amount (approaching 70%) in the winter. The values by individual plant group and season are given in Table F10. Not all the herbage can be grazed in any given season. There is an allowable use factor which varies between plant groups and seasons. For simplicity, this use factor applies to both the standing crop and the growth during the season involved. These values are given in Table F11. In general, these assigned use factors represent the fact that plants can be grazed more heavily during the fall and winter period when they are not growing than during the spring and summer when they are growing.

6.2 Estimates of Variances.

The mean values of all variables and parameters are not known with certainty. Thus we derive variances for key items. The logic behind the derivation procedure follows.

Van Dyne (1965) reported on variances of forage intake for individual sheep and cattle under grazingland conditions of abundant or limited feed supply. His standard deviations are about 19% of the mean forage intake for cattle and 29% of the mean for sheep. The standard deviations for sheep were higher with smaller or larger amounts of forage available than was the case for medium amounts. In contrast, for cattle the standard deviations were smaller for larger amounts of forage available but higher for smaller amounts of forage avilable. Using these standard deviations as guides, we have estimated the coefficients of variation of forage intake to be 12% early in the season for both cattle and bison, 18% in summer and fall, and 21% in winter. For sheep and pronghorn antelope we used coefficients of variation of 30% in the spring and winter but 24% in summer and fall. We applied these coefficients of variation to our mean values to calculate our standard deviations and hence, the variances.

Numerous workers have indicated that the variability of herbage growth from year to year is large on grazinglands. We assume that the usual conditions are bracketed by 50% variability from the mean, i.e., the drier years have 50% less herbage production than the normal years and the normal years may only be 50% of the producction of the wet years (Pendleton and Van Dyne 1980). Thus, with a normal value of 1000 kg ha^{-1}, the dry years would have 500 kg ha^{-1} and the wet years 2000 kg ha^{-1}. This of course, means there is not a normal distribution (statistically) of herbage biomass but one that is skewed to the right. However, for purposes of the present model we assume normality of distribution and assume that the usual dry and wet years are bracketed within 2 standard deviations of the mean. Thus, on the average, the standard deviation is 25% of the mean. However, the variability differs from plant group to plant group. It is most stable (i.e., lowest) for shrubs, next most stable for grasses, and least stable for forbs. Also, it differs from season to season according to the expected variability in precipitation and temperature conditions. Thus, it is most stable for spring, next most stable for summer, and least stable for fall. No growth occurs in the winter in the versions of the model we have developed. There is more variability in the

Table F10. Base data for examining proposed forage allocation models: Proportion of the standing crop lost during the grazing season.

Plant Group	L_{ik} in proportion Spring	Summer	Fall	Winter
Warm-season grasses	0.10	0.05	0.10	0.7
Cool-season grasses	0.05	0.10	0.50	0.7
Warm-season forbs	0.10	0.05	0.60	0.7
Cool-season forbs	0.10	0.20	0.60	0.7
Shrubs	0.05	0.05	0.20	0.7

Table F11. Base data for examining the proposed forage allocation models: Allowable use of the standing crop, in proportions.

Plant Group	U_{ik} in proportion Spring	Summer	Fall	Winter
Warm-season grasses	0.3	0.1	0.5	0.7
Cool-season grasses	0.1	0.3	0.5	0.7
Warm-season forbs	0.3	0.1	0.5	0.7
Cool-season forbs	0.1	0.3	0.5	0.7
Shrubs	0.1	0.1	0.3	0.7

production of the warm-season plants than there is in the cool-season plants. Thus, overall, by individual plant group or by season, the minimum variability is a coefficient of variation of 5% and the maximum is a coefficient of variation of 45%. A summary of the variances of the database is given in Table F12.

6.3 Conversion to Single-Season Values

Values for the various parameters used in the models were estimated on a seasonal basis. Thus, an annual estimate of the parameters, based on the seasonal estimates, was needed for the single-season or annual models. A simple arithmetic mean over all seasons, however, can not be biased on the side of the longer season as it should be. Therefore, it is desirable that such an estimate account for unequal length in seasons. This was done by weighting the arithmetic means by the number of days in each season (T_n). The general formula used for calculating the weighted means is:

$$PARAM_{ann} = \frac{\Sigma_{n=1}^{N} T_n PARAM_n}{{}_{n=1}^{N} T_n}$$

$$= \frac{\Sigma_{n=1}^{N} T_n PARAM_n}{365}$$

where $PARAM_{ann}$ is the weighted mean estimate, for the annual model, $PARAM_n$ is the original multiple season estimate and T_n is the number of days in each season which sums to 365.

Variances for the single-season models can be derived in the same way since coefficients of variation were originally estimated, rather than being the actual variances of the parameters. After calculating weighted annual means for the coefficients of variation, in the way outlined above, the variances can be easily derived.

The variables U, L, C, and D were all recalculated in this fashion for the single-season model. The initial standing crop, S, of the multiple season model was used directly as the standing crop for the single-season model. The growth of the standing crop, G, was summed over all the seasons for each plant group for its value in the single-season modeal. Lastly, the variablele M_4, reflecting the desired herbage in kilograms to be left of the range at the last season, through the site maintenance constraints, was used for the single-season data value. The single season database is given in Table F13.

Table F12. Variances of random variables entering into formulation of the model 6 group and the values used in the annual model 5 group. The variance values for S in the first season of the multiple-season models are the same as for S used in the annual models.

$Var[S_{i1}] = \{6.25,\ 0.0625,\ 0.25,\ 0.25\ 9.0\}$

$Var[G_{ik}]$ =	k = 1	2	3	4	Annual
i = 1	576.00	2916.00	0.00	0.00	6084.
2	100.00	4.00	36.00	0.00	697.
3	25.00	306.00	0.00	0.00	216.
4	81.00	2.25	4.00	0.00	160.
5	2.25	36.00	9.00	0.00	121.

$Var[C_{jk}]$ =	k = 1	2	3	4	Annual
j = 1	0.2258	1.2250	1.29	1.997	1.058
2	0.1137	0.6301	0.6767	1.059	.5519
3	0.0635	0.1004	0.1065	0.1998	.1290
4	0.0273	0.03779	0.02586	0.06503	.0418

Table F13. Base data for examining the proposed single-season forage allocation models.

Plant Data:

	S	G	U	L
	$kg \cdot ha^{-1}$		proportion	
Warm-season grasses	50.	600.	.45	.32
Cool-season grasses	5.	240.	.46	.40
Warm-season forbs	5.	70.	.45	.42
Cool-season forbs	5.	55.	.46	.46
Shrubs	15.	100.	.37	.33

Animal Data:

	C $kg\ an^{-1}\ day^{-1}$
Cattle	6.05
Bison	4.37
Sheep	1.33
Pronghorn Antelope	.757

Plant-Animal Data:

	D (a proportion of C)			
	Cattle	Bison	Sheep	Pronghorn
Warm-season grasses	.66	.39	.23	.19
Cool-season grasses	.27	.31	.27	.39
Warm-season forbs	.01	.07	.04	.04
Cool-season forbs	.04	.11	.15	.35
Shrubs	.02	.12	.31	.03

Constants

T = 365

H = 10,000

7. RESULTS OF MODEL RUNS ON A COMMON DATA SET

The six model series representing a total of 14 models were implemented, as discussed in section 3, using the common data set described in section 5. These various model runs enabled an evaluation of the influence of linearity versus non-linearity, single versus multiple seasons, weighting of the objective function versus non-weighting, and the differences between a stochastic versus a deterministic approach. In all of the models, the animal species considered are bison, cattle, sheep and pronghorn antelope. In the multiple-season models, the seasons represent spring, summer, fall, and winter.

7.1 Biological and Management Implications

The results of these models are next considered in terms of their biological and management implications. These implications are discussed through an evaluation of the differences in the three major characteristics of the model results. These are (i) the solution vector values, representing animal numbers, (ii) the binding constraints which determine the optimal solution vector and ensure, within the level of confidence of the data, that the grazing system is not unsafely exploited, and (iii) the range harbage utilization which represents the carrying capacity of the system for a particular combination of herbivores. The most important characteristic to both the range manager and to the biology of the grazing system is (iii), that of determining the carrying capacity, since there is no global optimal solution value vector. What is imperative, though, is that the long-term grazing regime does not sacrifice the stability of the ecosystem by either lowering the primary productivity of the system or its carrying capacity, or by causing a change in herbage species composition. A change in the latter would result in a subsequent change in the former.

Each of the principal characteristics of the model results is discussed next in turn, starting with the solution value vectors. The overall implications of these models to rangeland management is discussed again in the conclusions (section 8) with emphasis on the interpretation of sub-optimal solution value vectors as well.

7.1.1 Predictions of Optimal Animal Stocking.

The results of the model runs are summarized in Table F14. Recall, the characteristics of each model are identified in Table F1. Where stochasticity was used varying levels of confidence were used including 0 (which represents a deterministic framework or 0% confidence), and levels of 20, 40, 60, 80, 90, 95, and 99% confidence. In all the models, the optimal solution consists of either sheep and cattle together or cattle alone.

For the single-season models (1A, 1B, 3, 5A1, 5A2, 5B, and 5C) the dominant grazing animal in the solution vector was cattle. In one instance sheep were also assigned forage. Maximum numbers of cattle on a yearlong or single-season basis numbered 1134.

Table F14. Solution values in numbers of animals of the various models for consideration of forage allocation to four animal species.

		SOLUTION VALUES IN NUMBERS OF ANIMALS																			
		Cattle					Bison					Sheep					Pronghorn				
Model	Constraints type	Year-long	spring	summer	fall	winter	Year-long	spring	summer	fall	winter	Year-long	spring	summer	fall	winter	Year-long	spring	summer	fall	winter
1A, 5A1	Det.	933					0					915					0				
1B, 3, 4, 5A2, 5B, 5C	Det.	1134					0					0					0				
5A1, 5A2, 5B, 5C	20%	1058					0					0					0				
5A1, 5A2, 5B, 5C	40%	983					0					0					0				
5A1, 5A2, 5B, 5C	60%	902					0					0					0				
5A1, 5A2, 5B, 5C	80%	802					0					0					0				
5A1, 5A2, 5B, 5C	90%	728					0					0					0				
5A1, 5A2, 5B, 5C	95%	669					0					0					0				
5A1, 5A2, 5B, 5C	99%	147					0					0					0				
2A, 6A1	Det.		1586	1586	1586	556		0	0	0	0		595	595	595	0		0	0	0	0
6A1	20%		1534	1534	1534	547		0	0	0	0		538	538	538	0		0	0	0	0
6A1	40%		1489	1489	1489	544		0	0	0	0		468	468	468	0		0	0	0	0
6A1	60%		1429	1429	1429	536		0	0	0	0		389	389	389	0		0	0	0	0
6A1	80%		1347	1347	1347	526		0	0	0	0		282	282	282	0		0	0	0	0
6A1	90%		1279	1279	1279	517		0	0	0	0		192	192	192	0		0	0	0	0
6A1	95%		1220	1220	1220	509		0	0	0	0		115	115	115	0		0	0	0	0
2B, 6A2, 6B, 6C	Det		2105	1610	1610	401		0	0	0	0		0	0	0	0		0	0	0	0
6A2, 6B, 6C	20%		2094	1556	1556	552		0	0	0	0		0	0	0	0		0	0	0	0
6A2, 6B, 6C	40%		1897	1508	1508	547		0	0	0	0		0	0	0	0		0	0	0	0
6A2, 6B, 6C	60%		1769	1445	1445	539		0	0	0	0		0	0	0	0		0	0	0	0
6A2, 6B, 6C	80%		1593	1359	1359	528		0	0	0	0		0	0	0	0		0	0	0	0
6A2, 6B, 6C	90%		1447	1287	1287	518		0	0	0	0		0	0	0	0		0	0	0	0
6A2, 6B, 6C	95%		1321	1225	1225	510		0	0	0	0		0	0	0	0		0	0	0	0

In those models with multiple seasons (2A, 2B, 6A1, 6A2, 6B, and 6C), the same number of herbivores were included in the analysis as in models with a single season. Thus, in models 2A and 6A1, cattle and sheep were included and in models 2A1, 2B, 6B, and 6C cattle were the only herbivores in the optimal solution. The percent grazing loads carried by the cattle and sheep are shown in Table F15. Cattle always carried more than 90% of the grazing load in the multiple-season models.

By examining the characteristics of the models in Table F1 it can be seen that a comparison of the impact of single versus multiple season can be obtained from the output of models 1 versus 2 and 5 versus 6. In comparing models 1 and 2 it is shown that with multiple seasons, sheep accounted for less of the grazing load.

However, in the single-season models 1A, 1B, 5A1, and 5A2, solution vectors of cattle and sheep were equivalent to those of cattle alone in terms of total forage grazed, total herbage remaining (Table F16), and the number of animal unit equivalents (Table F15). This is a characteristic of the data set used for model evaluation which gave rise to two vertices mapping into the same point in the objective function (although formed by different active constraint lines).

7.1.2 <u>Prediction of Forage Used or Remaining</u>

In the multiple season models 2A, 2B, 6A1, and 6A2, the vertices representing cattle and sheep and cattle alone mapped into virtually the same objective function value as in the single-season models. Objective functions that were formulated to maximize the grazed forage (2A and 6A1) resulted in a slight increase in total utilization of forage, 26.9 versus 26.83 metric tons, as compared to a minimization of the remaining herbage as used in objective functions of models 2B and 6A2. As would be expected, there was slightly less herbage remaining (Table F16). Summing the remaining herbage over all seasons resulted in values of 42.47 and 42.71 metric tons when the remaining herbage was minimized and the forage grazed was maximized, respectively. However, both objective functions resulted in equivalent numbers of weighted (by season length) animal unit equivalent means of 711. Thus, the degree of allocation is essentially the same between the two objective functions although the vertices chosen, representing different binding constraints, resulted in different animal combinations.

In the constrained optimization programming problem, the optimal solution value vector always lies at the intersection of at least two constraints, which form a vertex in the feasible solution space. In the non-linear problem the optimal solution value need not necessarily lie on such a vertex but must at least lie on a constraint vector, (if the constraints are not superfluous to the problem), representing a boundary of the feasible solution space of the programming problem. Thus, in all cases a constraint vector or vectors forming a vertex will determine the optimal solution. These constraint vectors are referred to as the binding or limiting constraints since they limit any subsequent improvements in the optimal solution unless they are relaxed.

Table F15. Solution values in percentage of the grazing load allocated and the number of animal unit equivalents, based on a weighted seasonal mean, of the various models for consideration of forage allocation to four animal species.

SOLUTION VALUES IN PERCENTAGE OF THE GRAZING LOAD ALLOCATED AND THE GRAZING LOAD IN A.U.E.'S

Model	Constraints type	Cattle Year-long	Cattle spring	Cattle summer	Cattle fall	Cattle winter	Bison Year-long	Bison spring	Bison summer	Bison fall	Bison winter	Sheep Year-long	Sheep spring	Sheep summer	Sheep fall	Sheep winter	Pronghorn Year-long	Pronghorn spring	Pronghorn summer	Pronghorn fall	Pronghorn winter	A.U.E.'S Year-long*	A.U.E.'S spring	A.U.E.'S summer	A.U.E.'S fall	A.U.E.'S winter
1B, 5A1	Det.	82.3					0					17.9					0					689.				
1B, 3, 4, 5A2, 5B, 5C	Det.	100					0					0					0					691.				
5A1, 5A2, 5B, 5C	20%	100					0					0					0					645.				
5A1, 5A2, 5B, 5C	40%	100					0					0					0					599.				
5A1, 5A2, 5B, 5C	60%	100					0					0					0					549.				
5A1, 5A2, 5B, 5C	80%	100					0					0					0					488.				
5A1, 5A2, 5B, 5C	90%	100					0					0					0					443.				
5A1, 5A2, 5B, 5C	95%	100					0					0					0					408				
5A1, 5A2, 5B, 5C	99%	100					0					0					0					90.				
2A, 6A1	Det.		92.6	92.6	92.6	100		0	0	0	0		7.4	7.4	7.4	0		0	0	0	0	711	678	879	1083	417
6A1	20%		93.1	93.0	93.0	100		0	0	0	0		6.9	7.0	7.0	0		0	0	0	0	688	653	846	1043	410
6A1	40%		93.8	93.7	93.7	100		0	0	0	0		6.2	6.3	6.3	0		0	0	0	0	667	629	815	1004	407
6A1	60%		94.5	94.5	94.5	100		0	0	0	0		5.5	5.5	5.5	0		0	0	0	0	640	599	776	956	402
6A1	80%		95.8	95.7	95.7	100		0	0	0	0		4.2	4.3	4.3	0		0	0	0	0	603	557	722	890	394
6A1	90%		96.9	96.9	96.9	100		0	0	0	0		3.1	3.1	3.1	0		0	0	0	0	573	523	677	834	387
6A1	95%		98.0	98.0	98.0	100		0	0	0	0		2.0	2.0	2.0	0		0	0	0	0	546	493	639	787	381
2B, 6A2, 6B, 6C	Det.		100	100	100	100		0	0	0	0		0	0	0	0		0	0	0	0	711	833	826	1018	420
6A2, 6B, 6C	20%		100	100	100	100		0	0	0	0		0	0	0	0		0	0	0	0	683	793	798	954	413
6A2, 6B, 6C	40%		100	100	100	100		0	0	0	0		0	0	0	0		0	0	0	0	667	751	774	953	410
6A2, 6B, 6C	60%		100	100	100	100		0	0	0	0		0	0	0	0		0	0	0	0	640	709	741	913	404
6A2, 6B, 6C	80%		100	100	100	100		0	0	0	0		0	0	0	0		0	0	0	0	603	631	697	859	395
6A2, 6B, 6C	90%		100	100	100	100		0	0	0	0		0	0	0	0		0	0	0	0	573	573	660	813	385
6A2, 6B, 6C	95%		100	100	100	100		0	0	0	0		0	0	0	0		0	0	0	0	546	523	628	774	382

* A.U.E.'S yearlong values for the multiple season models are based weighted seasonal means.

Table F16. The available herbage and grazed forage by functional groups, their totals and the difference between their totals (metric tons) for the optimal combination of herbivores of the various models for consideration of forage allocation to four animal species. Entries with a * represent mean that the functional group was limiting to the solution vector.

AVAILABLE HERBAGE AND GRAZED FORAGE

		Available W.S.G. %					Grazed W.S.G. %					Available C.S.G. %				
Model	Constraints type	Year-long	spring	summer	fall	winter	Year-long	spring	summer	fall	winter	Year-long	spring	summer	fall	winter
1A, 5A1	Det.	60.4					58.4					20.5*				
1B, 3, 4, 5A2, 5B, 5C	Det.	60.4					66.0					20.5*				
5A1, 5A2, 5B, 5C	20%	60.4					58.4					20.5*				
5A1, 5A2, 5B, 5C	40%	60.4					66.0					20.5*				
5A1, 5A2, 5B, 5C	60%	60.4					66.0					20.5*				
5A1, 5A2, 5B, 5C	80%	60.4					66.0					20.5*				
5A1, 5A2, 5B, 5C	90%	60.4					66.0					20.5*				
5A1, 5A2, 5B, 5C	95%	60.4					66.0					20.5*				
5A1, 5A2, 5B, 5C	99%	60.4					66.0					20.5				
2A, 6A1	Det.		69.1	40.8*	72.0	69.0		57.4	59.9	64.5	69.0		17.2	39.6	14.0	11.4*
6A1	20%		69.1	40.7*	72.0	68.9		57.6	60.0	64.6	69.0		17.2	40.0	14.0	11.5*
6A1	40%		69.1	40.7*	72.0	68.8		57.8	60.3	64.8	69.0		17.2	40.0	14.0	11.6*
6A1	60%		69.1	40.7*	72.0	68.8		58.1	60.7	65.1	69.0		17.2	39.6	14.0	11.8*
6A1	80%		69.1	40.7*	71.9	68.7		58.5	61.2	65.5	69.0		17.2	39.6	14.1	11.9*
6A1	90%		69.1	40.7*	71.9	68.6		58.9	61.7	65.9	69.0		17.2	39.6	14.1	12.1*
6A1	95%		69.1	40.7*	71.9	68.6		59.3	62.2	66.3	69.0		17.2	39.6	14.1	12.2*
2B, 6A2, 6B, 6C	Det.		69.1	40.7*	71.2	68.1		60.0	63.0	67.0	69.0		17.2	39.4	13.9	11.5*
6A2, 6B, 6C	20%		69.1	40.7*	71.2	68.2		60.0	63.0	67.0	69.0		17.2	39.4	14.0	11.6*
6A2, 6B, 6C	40%		69.1	40.7*	71.7	68.2		60.0	63.0	67.0	69.0		17.2	39.5	14.0	11.7*
6A2, 6B, 6C	60%		69.1	40.7*	71.7	68.3		60.0	63.0	67.0	69.0		17.2	39.5	14.0	11.8*
6A2, 6B, 6C	80%		69.1	40.7*	71.8	68.3		60.0	63.0	67.0	69.0		17.2	39.5	14.1	12.0*
6A2, 6B, 6C	90%		69.1	40.7*	71.8	68.4		60.0	63.0	67.0	69.0		17.2	39.5	14.1	12.1*
6A2, 6B, 6C	95%		69.1	40.7*	71.8	68.4		60.0	63.0	67.0	69.0		17.2	39.6	14.1	12.2*

Table F16. (Continued).

		Grazed C.S.G. %					Available W.S.F. %					Grazed W.S.F. %				
Model	Constraints type	Year-long	spring	summer	fall	winter	Year-long	spring	summer	fall	winter	Year-long	spring	summer	fall	winter
1A, 5A1	Det.	27.0					5.9					1.5				
1B, 3, 4, 5A2, 5B, 5C	Det.	27.0					5.9					1.0				
5A1, 5A2, 5B, 5C	20%	27.0					5.9					1.0				
5A1, 5A2, 5B, 5C	40%	27.0					5.9					1.0				
5A1, 5A2, 5B, 5C	60%	27.0					5.9					1.0				
5A1, 5A2, 5B, 5C	80%	27.0					5.9					1.0				
5A1, 5A2, 5B, 5C	90%	27.0					5.9					1.0				
5A1, 5A2, 5B, 5C	95%	27.0					5.9					1.0				
5A1, 5A2, 5B, 5C	99%	27.0					5.9					1.0				
2A, 6A1	Det.		26.0	26.6	26.9	27.0		6.0	4.8	4.1	4.3		4.6	2.5	1.0	0.0
6A1	20%		26.1	26.7	26.9	27.0		6.0	4.8	4.0	4.2		4.6	2.4	1.0	0.0
6A1	40%		26.2	26.7	26.9	27.0		6.0	4.8	4.0	4.2		4.5	2.4	1.0	0.0
6A1	60%		26.3	26.7	26.9	27.0		6.0	4.8	4.0	4.2		4.4	2.3	1.0	0.0
6A1	80%		26.4	26.8	27.0	27.0		6.0	4.8	4.0	4.1		4.3	2.3	1.0	0.0
6A1	90%		26.6	26.8	27.0	27.0		6.0	4.8	4.0	4.1		4.2	2.2	1.0	0.0
6A1	95%		26.7	26.9	27.0	27.0		6.0	4.8	4.0	4.1		4.2	2.1	1.0	0.0
2B, 6A2, 6B, 6C	Det.		27.0	27.0	27.0	27.0		6.0	4.9	4.1	4.3		4.0	2.0	1.0	0.0
6A2, 6B, 6C	20%		27.0	27.0	27.0	27.0		6.0	4.9	4.1	4.2		4.0	2.0	1.0	0.0
6A2, 6B, 6C	40%		27.0	27.0	27.0	27.0		6.0	4.8	4.1	4.2		4.0	2.0	1.0	0.0
6A2, 6B, 6C	60%		27.0	27.0	27.0	27.0		6.0	4.8	4.1	4.2		4.0	2.0	1.0	0.0
6A2, 6B, 6C	80%		27.0	27.0	27.0	27.0		6.0	4.8	4.0	4.1		4.0	2.0	1.0	0.0
6A2, 6B, 6C	90%		27.0	27.0	27.0	27.0		6.0	4.8	4.0	4.1		4.0	2.0	1.0	0.0
6A2, 6B, 6C	95%		27.0	27.0	27.0	27.0		6.0	4.8	4.0	4.1		4.0	2.0	1.0	0.0

Table F16. (Continued).

Model	Constraints type	Available C.S.F. % Year-long	spring	summer	fall	winter	Grazed C.S.F. % Year-long	spring	summer	fall	winter	Available shrubs % Year-long	spring	summer	fall	winter
1A, 5A1	Det.	4.5*					6.0					8.6				
1B, 3, 4, 5A2, 5B, 5C	Det	4.5					4.0					8.6				
5A1, 5A2, 5B, 5C	20%	4.5					4.0					8.6				
5A1, 5A2, 5B, 5C	40%	4.5					4.0					8.6				
5A1, 5A2, 5B, 5C	60%	4.5					4.0					8.6				
5A1, 5A2, 5B, 5C	80%	4.5					4.0					8.6				
5A1, 5A2, 5B, 5C	90%	4.5					4.0					8.6				
5A1, 5A2, 5B, 5C	95%	4.5					4.0					8.6				
5A1, 5A2, 5B, 5C	99%	4.5*					4.0					8.6				
2A, 6A1	Det.		4.0*	7.8	2.1	1.8		11.1	8.5	3.2	1.0		3.8	7.0	7.9	13.6
6A1	20%		4.0*	7.9	2.1	1.8		10.9	8.4	3.2	1.0		3.9	7.0	7.9	13.5
6A1	40%		4.0*	7.9	2.1	1.9		10.7	8.3	3.2	1.0		3.8	7.0	7.8	13.4
6A1	60%		4.0*	7.9	2.2	1.9		10.5	8.1	3.2	1.0		3.8	7.0	7.9	13.4
6A1	80%		4.0*	8.0	2.2	2.0		10.2	7.9	3.1	1.0		3.8	6.9	7.8	13.2
6A1	90%		4.0*	8.0	2.2	2.0		9.9	7.6	3.1	1.0		3.8	6.9	7.7	13.1
6A1	95%		4.0*	8.0	2.3	2.1		9.6	7.4	3.1	1.0		3.8	6.9	7.7	13.1
2B, 6A2, 6B, 6C	Det.		4.0*	7.9	2.2	2.0		9.0	7.0	3.0	1.0		3.8	7.1	3.1	14.1
6A2, 6B, 6C	20%		4.0*	7.9	2.2	2.0		9.0	7.0	3.0	1.0		3.9	7.1	8.0	14.0
6A2, 6B, 6C	40%		4.0*	8.0	2.2	2.0		9.0	7.0	3.0	1.0		3.8	7.0	8.0	13.9
6A2, 6B, 6C	60%		4.0*	8.0	2.2	2.0		9.0	7.0	3.0	1.0		3.8	7.0	7.9	13.7
6A2, 6B, 6C	80%		4.0*	8.0	2.3	2.1		9.0	7.0	3.0	1.0		3.8	7.0	7.9	13.5
6A2, 6B, 6C	90%		4.0*	8.0	2.3	2.1		9.0	7.0	3.0	1.0		3.8	7.0	7.8	13.3
6A2, 6B, 6C	95%		4.0*	8.0	2.3	2.1		9.0	7.0	3.0	1.0		3.8	6.9	7.7	13.2

Table F16. (Continued).

Model	Constraints type	Grazed shrubs % Year-long	spring	summer	fall	winter	Total Available MT Year-long	spring	summer	fall	winter	Total Grazed MT Year-long	spring	summer	fall	winter
1A, 5A1	Det.	7.1					32.95					25.04				
1B, 3, 4, 5A2 5B, 5C	Det.	2.0					32.95					25.04				
5A1, 5A2, 5B, 5C	20%	2.0					32.95					23.37				
5A1, 5A2, 5B, 5C	40%	2.0					32.95					21.71				
5A1, 5A2, 5B, 5C	60%	2.0					32.95					19.91				
5A1, 5A2, 5B, 5C	80%	2.0					32.95					17.71				
5A1, 5A2, 5B, 5C	90%	2.0					32.95					16.07				
5A1, 5A2, 5B, 5C	95%	2.0					32.95					14.78				
5A1, 5A2, 5B, 5C	99%	2.0					32.95					3.254				
2A, 6A1	Det.		0.9	2.6	4.4	3.0		11.33	13.93	31.94	12.41	26.9	4.07	9.48	8.11	5.24
6A1	20%		0.8	2.5	4.2	3.0		11.33	13.95	32.11	12.55		3.92	9.13	7.81	5.16
6A1	40%		0.7	2.3	4.0	3.0		11.33	13.97	32.27	12.68		3.77	8.80	7.52	5.12
6A1	60%		0.7	2.2	3.8	3.0		11.33	14.00	32.47	12.85		3.59	8.37	7.16	5.05
6A1	80%		0.5	1.9	3.4	3.0		11.33	14.04	32.76	13.07		3.34	7.79	6.66	4.95
6A1	90%		0.4	1.7	3.0	3.0		11.33	14.07	32.99	13.26		3.14	7.31	6.25	4.87
6A1	95%		0.2	1.4	2.6	3.0		11.33	14.10	33.20	13.42		2.96	6.89	5.89	4.80
2B, 6A2, 6B, 6C	Det.		0.0	1.0	2.0	3.0		11.33	13.79	31.73	12.45	26.83	5.21	8.91	7.62	5.29
6A2, 6B, 6C	20%		0.0	1.0	2.0	3.0		11.33	13.82	31.93	12.58		4.76	[illegible]	7.35	5.23
6A2, 6B, 6C	40%		0.0	1.0	2.0	3.0		11.33	13.86	32.11	12.71		4.51	8.35	7.14	5.16
6A2, 6B, 6C	60%		0.0	1.0	2.0	3.0		11.33	13.91	32.34	12.87		4.20	8.00	6.84	5.05
6A2, 6B, 6C	80%		0.0	1.0	2.0	3.0		11.33	13.98	32.66	13.09		3.78	7.52	6.43	4.98
6A2, 6B, 6C	90%		0.0	1.0	2.0	3.0		11.33	14.03	32.93	13.27		3.44	7.12	6.09	4.88
6A2, 6B, 6C	95%		0.0	1.0	2.0	3.0		11.33	14.08	33.16	13.43		3.14	6.78	5.80	4.81

Table F16. (Continued).

		Available - Grazed MT				
Model	Constraints type	Year-long	spring	summer	fall	winter
1A, 5A1	Det.	7.91				
1B, 3, 4, 5A2 5B, 5C	Det.	7.91				
5A1, 5A2, 5B, 5C	20%	9.58				
5A1, 5A2, 5B, 5C	40%	11.24				
5A1, 5A2, 5B, 5C	60%	13.04				
5A1, 5A2, 5B, 5C	80%	15.24				
5A1, 5A2, 5B, 5C	90%	16.88				
5A1, 5A2, 5B, 5C	95%	18.17				
5A1, 5A2, 5B, 5C	99%	29.7				
2A, 6A1	Det.	42.71	7.26	4.45	23.83	7.17
6A1	20%	43.92	7.41	4.82	24.3	7.39
6A1	40%	45.04	7.56	5.17	24.75	7.56
6A1	60%	46.48	7.74	5.63	25.31	7.8
6A1	80%	48.46	7.99	6.25	26.1	8.12
6A1	90%	50.08	8.19	6.76	26.74	8.39
6A1	95%	51.51	8.37	7.21	27.31	8.62
2B, 6A2, 6B, 6C	Det.	42.47	6.32	4.88	24.11	7.16
6A2, 6B, 6C	20%	43.73	6.57	5.21	24.57	7.38
6A2, 6B, 6C	40%	44.85	6.82	5.51	24.97	7.55
6A2, 6B, 6C	60%	46.33	7.13	5.91	25.5	7.79
6A2, 6B, 6C	80%	48.35	7.55	6.46	26.23	8.11
6A2, 6B, 6C	90%	49.76	7.89	6.91	26.57	8.39
6A2, 6B, 6C	95%	51.47	8.19	7.3	27.36	8.62

The binding constraints of the various models are shown in Table F17. In the single-season models 1A and 5A1, the solution vector of cattle and sheep was due to the vertex formed by the active constraints of cool-season grasses and cool-season forbs, while in the remaining single-season models, 1B, 3, 4, 5A2, 5B, and 5C, the solution vector of cattle alone was due solely to cool-season grass constraint. In all of the multiple-season models, warm-season grasses in the summer, cool-season grasses in the winter, and cool-season forbs in the spring were limiting to the two different solution vectors of cattle alone and cattle and sheep. The difference in solution vectors arose due to the no-seasonal-increase constraints. In model 6A1, all-seasonal-increase constraints were limiting except cattle and sheep in the winter, which with the active plant constraints gave rise to an optimal vertex of cattle and sheep. In all the other multiple-season models, 2B, 6A2, 6B, and 6C, the same constraints applied with the exception of winter sheep, which with the active plant constraints resulted in the optimal vertex of cattle alone.

The constraining plant groups were cool-season forbs in season 1, warm-season grasses in season 2, and cool-season grasses in season 4. None of the plant groups constrained the solution in more than one season.

The amount of herbage left varied considerably among the different plant groups. These values are summarized in Table F16. At no time were the site maintenance contraints ever limiting.

7.2 Comparison of Model Operation Characteristics

In comparison to the amount of herbage remaining after grazing under the solution with the deterministic version of the model, any stochastic model had more herbage remaining. The amount of herbage remaining by individual plant group and season increased steadily as the confidence level of satisfying the constraints increased. The amount of herbage remaining of different plant groups at different seasons with 95% confidence was about 5% larger than the amount of herbage remaining for the same plants and seasons with 0% confidence in satisfying the constraints.

Due to the characteristics of the data set and the no-seasonal-increase constraints employed by the models, the influence of weighting and the quadratic forms could not be adequately evaluated. Models 3, 6B, and 6C, representing weighting, quadratic and both weighting and quadratic forms, respectively, all selected solution vectors of cattle alone in the identical fashion to their non-weighted, linear counterparts, models 1B and 6A2. In the deterministic multiple-season model, 6A2, the remaining herbage varied from 4.88 to 24.11 metric tons. The quadratic nature of the objective function of model 6B attempted to smooth out this large variation which occurred principally in the fall season. However, there is not another feasible vertex within the solution space that would better reduce these differences since in order to do so, grazing would have to be increased in the third season which would violate the no-seasonal-increase constraints. If the data set was such that the magnitudes of remaining herbage was decreasing with time rather than increasing, due to perhaps greater loss and smaller utilization factors in the fall season, then it would be feasible for the effect of the quadratic form to be observed without the violation or relaxation of the no-seasonal-increase

Table F17. Binding constraints of the various models at the optimal solution values for consideration of forage allocation to four animals species. In addition to the binding constraints listed below, all of the no-seasonal-increase constraints were binding, except for winter cattle in all of the multiple season models. Another exception was for winter sheep in models 6A1 and 2A.

Models	WSG	CSG		CSF	
	summer	yearlong	winter	yearlong	spring
1A, 5A1 (det.)		*		*	
1B, 3, 4, 5A2, 5B, 5C (All) and 5A1 (chance levels only)		*			
2A, 2B, 6A1, 6A2, 6B, 6C (All) (All multiple-season models)	*		*		*

constraints. The expected effect of weighting is identical to that of the quadratic form since the relative degree of magnitude in the available herbage on a seasonal basis followed that of the remaining herbage. Thus, weighting also attempts to reduce the large increase in the remaining herbage found in fall, due to an increase in warm-season grasses, by attempting to allocate more of the warm-season grasses. However, as mentioned above, this is not feasible without violating or relaxing the no-seasonal-increase constraints.

The increase in herbage over the first three seasons is due to the increase in the allowable use factors which more than double the previous season values. The increase in allowable use with time strongly masks the tendency to decrease the available herbage which results from decreased growth and a general increase in the loss factors with time.

The impact of stochasticizing the models was to reduce the number of animals allocated and, thus, decrease the number of animal unit equivalents. In addition, stochasticizing the models increased both the remaining herbage and available herbage on a seasonal and plant basis due to decreased grazing allocations. In virtually all cases, stochasticity did not alter the basis (i.e., herbivores selected), only the magnitudes of the values in the ways mentioned. The only exception to this was model 5A1 in which sheep dropped out of all of the chance-constraint levels implemented.

The effect of the chance constraints can best be illustrated as follows. There are two possible ways in which the model constraints can be affected since the penalty functions of the chance constraints are a linear combination of the deterministic constraints. Altering the slope of the constraints, is one way, which is due to the values of penalty functions associated with the left-hand sides of the constraints, i.e., the unknown herbivores. The other way is through altering the constraints intersection with the decision variables bounds which is due to the right-hand side of the expression or the constants. This intersection is equivalent to the b intercept in the equation of a straight line where $y = mx+b$. Changes in right-hand side values can be visualized as a lowering of the constraint lines while changes to the left-hand side affects the slope of the lines. Since the differential effect of these properties is slight due to relatively small variations in the coefficients of variation for the consumption rates and standing crops at the first season and the growth in the standing crop, the effect was to alter the slopes and the intercept of constraint lines in a similar fashion throughout. Therefore, the same constraints remained active which resulted in selecting the same vertex, although in a smaller solution space, except in model 5A1. There, the differential effects caused selection of the other optimal vertex of cattle alone. (The vertex of cattle and sheep together dropped more quickly in objective function value than did that of cattle alone.)

8. SUMMARY AND CONCLUSIONS

The optimal forage allocation problem is considered as an optimization problem which was first conceptualized by Van Dyne and Rebman (1967). It then went through several developmental stages, reviewed by Van Dyne and Kortopates (1981), until it reached the present conceptual form (Janisz, et al. 1979, Chapter A). The problem may be divided into three general areas of study. These are choosing a currency to be optimized, choosing an appropriate cost-benefit function (which may or may not be subject to various constraints) and lastly solving for an optimum.

The cost-benefit function or objective function is concerned with minimizing the remaining available herbage, the currency, upon completion of the grazing season. As such, the model determines, optimally, how many of each of several different species of herbivores to stock on a given rangeland which has several plant species, so as to achieve the maximum allowable use of the vegetation as a whole. Thus, the unknowns or the solution vector consists of the number of animals of each of the different species allowed to graze on the range. In our model the animal species are bison, cattle, sheep, and pronghorn antelope.

The model is constrained by either two or four systems of constraints, depending on the aspect of seasonality. All of the models are constrained to prevent the over-grazing of any important individual plant species or groups and to maintain a sufficient level of herbage on the range so as to protect the soil from wind and water erosion. Unique to the multiple-season models are constraints to limit undue movement of the herbivores in and out of the grazing areas at different seasons and to ensure that all remaining phytomass at the end of one grazing season is fully present at the start of the next season. These constraints are aimed at preserving the stability of the range ecosystem and at providing tractable solution values to aid the manager in his decision-making process.

In order to solve for an optimum, the conceptual model has been implemented in several forms, referred to as the standard forms. The standard forms are a specific generalized form that any problem of a particluar class can be transformed into thereby allowing it to be solved by any one of a group of algorithms. Six different groups of problems, representing three different classes of standard forms, are derived from the original conceptual model. These three classes represent the standard forms of the Linear Programming Problem (L.P.P.), the Quadratic Programming Problem (Q.P.P.), and the Non-Linear Programming Problem (N.L.P.P.); where the first two are in a matrix form and the latter is in the form of a user supplied FORTRAN coded subroutine.

Six different groups of models, representing different model structures, are discussed. Some of the groups consider different cases and together they represent a total of 14 optimization models. These models range in structure from the simplest, linear, single-season, deterministic model to the more complex, non-linear, multiple-season, weighted, stochastic model with chance-constraints. The groups of models allow for the comparison of the aspects of seasonality, weighting, linearity or non-linearity, deterministic

or stochastic approaches and the use of specific standardized problem forms (L.P.P. and Q.P.P.) or a generalized problem standard form (N.L.P.P.).

Informational requirements of the various model structures differ in resolution rather than content. The requirements include: the number of seasons of the year grazing will occur and their respective lengths; the standing crop at the start of the first grazing season and the expected amount of plant growth under normal grazing use in each season; the amount of loss in the standing crop of vegetation due to trampling, shattering and decay; the allowable use factors for individual plant species or groups by season; the daily forage requirement of each herbivore species in phytomass; the dietary botanical composition of each herbivore during each grazing season for a specific grazing area and its conditions; and lastly the total land area to be grazed which is enclosed by suitable boundaries and is as homogeneous as possible with respect to the plant communities. The multiple season models require the data on a seasonal basis whereas the single-season models require the data on an annual basis.

The solution value vectors were determined for, and contrasted between, the 14 optimization models. In addition, the solving of the optimization models produced other important information through sensitivity analyses. These include the limiting constraints, which were either a limiting plant group or a limiting seasonal increase of a herbivore; or a combination thereof. Also included were the amounts of the available plant groups, after the first season; the utilization of the plant groups, in terms of total proportion, by individual herbivore species and by the total combination of herbivore species; and the total number of animal unit equivalents; all of which are expressed on a seasonal as well as an annual basis.

Examination of various sections in this chapter will clearly suggest that there is no global optimal answer in forage allocation. The strength of the mathematical programming approach is to provide an easy way to get alternative answers rather than a single answer. The resource manager should use the tool of optimization analysis as a guide in decision making not one to generate prescriptions. Thus, it is important to use the rapid-calculation tool as a way of checking different uncertainties and assumptions. Progressively, the manager involved should question the validity of the data entered into the analysis, and perhaps even the form of the model, by making more than one model run. One can question the preference idea or concept (whether it be entered directly or be calculated from proper use factors), the validity of the allowable use factors assigned, the possible error (i.e., variance) in the amounts of available herbage allowed, and so forth. Only after making alternative runs and checking their own intuitive knowledge, should the resource managers make the final resource allocation decision.

Because each set of resource managers may have different amounts of inputs and ideas, then for the greatest utility in the long run, the optimal forage allocation modeling procedure should be done in an iterative mode. This means that the resource manager should be able to input remotely the values to be used for a particular run. By "remote" we mean that they may be in a district office or a state office whereas the main program(s) may reside on a computer hundreds or even thousands of kilometers away. The base data derived from forage inventory studies should be available in computer memory files. The base data should be examined, questioned, and modified by the

resource managers. Similarly the base data or information regarding allowable use factors, proper use factors, dietary preferences, and other such information should be made available for modification or use from a point remote to the central data bank. In no case should the manager draw upon and use data or parameters he has not seen and evaluated.

One cannot overstress the importance and meaning in that there is no single global optimal answer to the forage allocation model. Any model has both its pitfalls and disadvantages. The major drawback of the forage allocation models thus far is their inability to suggest a global optimal combination of herbivores when in practical terms one does not exist. Thus, even though one particular combination of herbivores is allocated by the model as the optimal solution, it should be recognized that there are many suboptimal solutions representing different combinations of herbivores that may not differ significantly from the optimal solution in the amount of total herbage remaining or grazed.

What the models do best is to determine the carrying capcity for the optimal combination of herbivores. Display of not only the single "best" combination of herbivores, but also the top three or more combinations of herbivores, ranked from the optimal to lower degrees of efficiency in utilizing as much of the avialable herbage as possible, represents the most useful and practical utility of the optimization models. It has been illustrated in this chapter that a suboptimal combination of herbivores may, in fact, utilize the available herbage to a range of within 1/2 kilogram of the optimal solution in which a total of some 30 metric tons is considered. The manager must, therefore, deem how much of a loss of the potential grazing load (optimal solution vector) is tolerable for a more preferable combination of herbivores for reasons that may be specific to the case at hand. Not until each manager can quantitatively express the biological, economic, social, and political factors and respective data that is incorporated into the forage allocation decision process will such a model be able to pick the best desirable combination of herbivores. It is quite doubtful that a model could ever make the ultimate decision of forage allocation. It is up to the manager in each specific case to weigh the "pluses and minuses" of each different strategy and then implement the most desirable scenario.

The models do represent a very powerful tool available to the manager. The models can greatly aid the decision-making process by quantitatively establishing not the best but a group of the best biologically feasible combinations of herbivores. These are ranked by their efficiency to utilize the herbage, the degree of their utilization as a combination of herbivores and in proper number such that over-grazing will not occur.

Through a sensitivity analysis, which could be incorporated into a model specifically designed for management, not only could other suboptimal combinations be derived but the most heavily used and most limiting plant groups as well. This constrasts greatly with simulation models where generally many runs are required and yet the sensitivity of a certain parameter in relation to others is still not quantitatively known. Through just one optimization model run, a total sensitivity analysis is derived for that combination of decision variables or herbivores and with each additional pivot of the tableau the equivalent is derived for the next best suboptimal combination. Thus, through a one-time sizable application of optimization

theory and its incorporation into a complete model software package for the manager, the analysis of such can be reduced to the task of reading output which is as specifically to the point as possible. Generally one run should be able to tell all about the model and the data set used. With the knowledge of limiting plant groups, alternative management schemes could be considered. One possibility would be the use of feed supplements that could greatly aid the range manager in improving management schemes based on a more rational biological foundation.

Some Conclusions From Our Model Runs

Our model runs suggest the following:

* As presently formulated, constraints on the protection of the sites are never binding since maintenance levels are set at less than 200 kg per 10,000 ha for all the herbage while the limiting overgrazing constraints insure remaining herbage to a level of at least 1 MT or more due to the allowable use factors.

* When different objective functions are formulated for a given set of constraints in mathematical programming forage allocation optimization models, generally similar results will be obtained for the different models. It is principally the characteristics of the data set and the various systems of constraints that determines the solution space.

* With quadratic least-squares objective functions in optimization models for forage allocation, weighting functions which increase the influence of plants of high abundance seem more appropriate than those which increase the influence of plants of low abundance. This is because in the objective function one is dealing with a square of differences between available and grazed forage which tends to increase as the available herbage increases.

* The effects of weighting the objective function or of any additional characteristic of the objective function can only be seen if there does indeed exist another feasible point which might better serve such an additional characteristic. Thus, in order to show the effects of several different objective function characteristics, several data sets should be employed.

* The principle area of model formulation that could most benefit from improvement is that of the no-seasonal-increase constraint system. This system of constraints prohibits any degree of seasonal increase in any of the herbivores. As a result of this, it is the most restrictive constraint system in relation to herbivore diversity as well as to forage allocation in latter seasons when there is an increase in the available herbage over that of the initial season. This

constraint system was indeed responsible for the bulk of remaining ungrazed herbage as derived from the particular data set used herein. Other methodologies that restrict animal number changes in both directions may be more desirable. A simple method would be to allow limited changes in animal number perhaps as a proportion of the previous season's numbers. This however would double the number of seasonal increase constraints. Another method would be to minimize the changes in animal numbers as well as forage remaining.

* Based on our present modelling runs with multiple seasons, the constraining plants banning more animals being allowed on the range are likely to be found early in the grazing year rather than late in the grazing year, since animal numbers are only allowed to decrease with time and thus must appear in the first season if at all.

* At present, the stochastic models result in lower animal unit equivalent numbers than do the deterministic models. This reflects the cost of being certain that constraints will be met.

* At present, using the means and variances we have assumed for input parameters, we can not set up stochastic forage allocation optimization models with more than 95% confidence for multiple-season models and more than 99% confidence for the single-season models that the constaints will be met.

* Meeting constraints with 95% confidence results in about 10 to 40% larger amount of herbage remaining ungrazed for the same plants and seasons than does meeting constraints with 20% confidence.

Some main information needs include the following:

* Allowable use factors are a necessary component in forage allocation modelling decision making. This information is widely scattered in the scientific and technical literature and needs to be researched, synthesized, and analyzed.

* Botanical composition information, such as that derived from microscopic analysis of fecal samples collected from the range, can provide a useful input into the forage allocation decision making process. However, errors and biases in such data need to be assessed carefully.

* We know relatively little about losses of vegetation to natural causes other than grazing. This information needs to be researched and summarized for use in forage allocation models.

* More work is needed on calculating preferences indexes that are linear in scaling and that reflect both the forage grazed and the herbage available.

* If standing crop information is used in a forage allocation model, it should be adjusted or corrected to the long-term average. We need better methods to adjust or correct a given year's forage production to the long-term climatic mean.

* At present, we know very little about the covariances among the different parameters entered into the formulation of optimal forage allocation models. However, we have reasonably good estimates of many of the variances. Our weakest information is about dietary botanical composition or forage preference.

* Presently formulated mathematical programming forage allocation models do not readily allow for inclusion of growth and reproduction of animals during the interval of grazing for which an optimum solution is being sought. Further work should be done in this area.

* The present paper deals with optimizing forage use as the objective function. Further work needs to be done on synthesizing information for and then developing objective functions and constraints for maximizing nutrient utilization from the range, digestible nutrient intake, red meat production, and economic benefits from all grazingland uses.

* The usual assumption in formulating mathematical programming forage allocation models is that all plants in a given area are available to all animal species. Further work is needed to put topographic or other spatial considerations into these models.

Some conclusions considering the use of forage allocation models are:

* Renewable resource managers are becoming increasingly familiar with use of mathematical programming optimization methods as aids to decision-making. We can expect an increase in adaptation and usage of mathematical programming optimization models in forage allocation decision-making.

* There are a wide variety of computational algorithms available to handle linear, quadratic, or non-linear programming models for forage allocation, each of which is best suited for a specific application. The generalized non-linear codes are adequate for handling linear and quadratic models. However, these are certainly outperformed by the respective specialist codes for linear and quadratic problems.

* Forage allocation optimization models will be of most value in the resource management decision-making community if the resource managers are able to input values remotely to be used in each particular run and if they can make and compare the results of several different model runs.

* If there is sufficient aggregation of small areas into larger areas in formulating the mathematical programming optimization models for forage allocation, and if there is a reasonable number of individual plant species treated (perhaps less than a dozen), then computation times are not excessive for the routine use of this tool in resource management decision making.

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APPENDIX I

Notational Conventions, Definitions of Variables and Symbols

Mathematical Notation Conventions

A matrix is a rectangular array of numbers, called elements. When a variable is defined as a matrix it is denoted by capital letter, e.g., A. A vector is a column of elements and is denoted by a lower case letter, e.g., a. Thus:

$$A = \begin{bmatrix} A_{11}, & A_{12}, \ldots A_{1n} \\ A_{21}, & A_{22}, \ldots A_{2n} \\ \vdots & \\ a_{m1}, & A_{m2}, \ldots A_{mn} \end{bmatrix} \qquad a = \begin{bmatrix} a_1 \\ a_2 \\ \vdots \\ a_m \end{bmatrix}$$

The transpose of an m x n matrix A is the n x m matrix $A^T{}_{ij} = A_{ji}$. Also, the transpose of a column vector a is the row vector a^T. The product A B of an m x n matrix A and an n x p matrix B is the m x p matrix C with elements:

$$C_{ij} = \Sigma_{k=1}^{n} A_{ik} B_{kn} \; .$$

$$X = \Sigma_{n=1}^{N} Y_n$$

refers to the summation of variables Y_1, $Y_2, \ldots Y_n$ such that:

$X = Y_1 + Y_2 + \ldots + Y_n$

$$X = \Pi_{n=1}^{N} Y_n$$

refers to the product of variables Y_1, $Y_2, \ldots,$ Y_n such that:

$X = Y_1 \cdot Y_2 \cdot \ldots \cdot Y_n$.

Note that:

$$\Sigma_{m=1}^{n} X_m \Pi_{l=m+1}^{n} Y_1$$

$$<===>$$

$$\Sigma_{m=1}^{n-1} X_m \Pi_{l=m+1}^{n} Y_1 + X_n .$$

Matrix notation is used in the discussion of the standard form models of the L.P.P. and Q.P.P. and the chance constraints. These standard form variables, A, b, c, u, and Q, are not related to the forage allocation model variables; a list of which is given next.

List and Definition of Symbols

Only those symbols used in the proposed model (see section on Current Optimization Approaches) are listed here, see Chapter F for all others.

A_i, A_{in} = Total allowable available herbage of plant group i at the beginning of stage n ($kg \cdot ha^{-1}$)
an = Animals
B_j, B_{jn} = Minimum allowable number of herbivore j during stage n (an)
C_j, C_{jn} = Consumption rate of herbivore j during season n ($kg \cdot an^{-1} \cdot d^{-1}$)
D_{ij}, D_{ijn} = Relative preference of herbivore j during season n for plant group i (a proportion)
e_i = The degree of error by which over-grazing _a posterori_ may occur due to uncertainty in the random variables (U, G, L, S, C, and D)
E = Expectation operator
Exponent = Used to denote portions of the objective function which are raised to powers other than 1.0
G_i, G_{in} = Additional gain in the standing crop of plant group i during stage n ($kg \cdot ha^{-1}$)
H = Land area (ha)
ha = Hectares
i, I = Index for plant groups where i = 1 to I
j, J = Index for herbivores where j = 1 to J
$k_{VARIABLES}$ = Fractiles corresponding to $(1- {}_i)$ of each of the respective random variables
kg = Kilograms
L_i, L_{in} = Loss in standing crop of plant group i during season n (a proportion)
n, N = Index for seasons where n = 1 to N
R_{ij}, R_{ijn} = Total grazing requirement of herbivore j for plant group i during season n ($kg \cdot an^{-1}$)
S_i, S_{in} = Standing Crop of plant group i at the beginning of season n ($kg \cdot ha^{-1}$)
T = Transpose operator
T_n = Number of days in season n (d)
U_i, U_{in} = Allowable use of plant group i at season n (a proportion)
VAR = Variance operator
X_j, X_{jn} = number of herbivore j during season n (an)
Z_j, Z_{jn} = Maximum allowable number of herbivore j during season n (an)

Σ = Summation operator
Π = Product operator
∂ = Partial derivative operator
∇ = Gradient operator
$\in$ = Belongs to the set of
E^n = An n-dimensional Euclidian space
<===> = If and only if

List and Definition of Symbols

Only those symbols used in the ... are listed here ...
Definitions ... in ...

A_i, A_{in} = Total allowable available herbage of plant group ... at beginning of stage n (kg ha^{-1})

an = Animals

B_i, B_{in} = Minimum allowable number of ... during stage (an)

C_j, C_{jn} = Consumption rate of herbivore ... during season (kg an^{-1} day^{-1})

D_{ij}, D_{ijn} = Relative preference of herbivore j for plant group (index ...)

e = The degree of error ...

... = ... in the ... and G)

L = Lagrangian operator

Lagrangian = used to ... of the ... raised to ...

G_i, G_{in} = Additional gain in the standing crop of plant group during stage n (kg ha^{-1})

... = Land area (ha)

ha = Hectares

i, I = Index for plant groups where i = 1 to I

j, J = Index for herbivore groups j = 1 to J

... = ... as ... respective random variables

kg = Kilograms

L_i, L_{in} = Loss in standing crop of plant group ... (proportion)

n, N = Index for seasons where n = 1 to N

R_{ij}, R_{ijn} = Total grazing requirement of herbivore j for ... during season n (kg ha^{-1})

S_i, S_{in} = Standing crop of plant group i at the beginning ... (kg ha^{-1})

T = Transpose operator

T_n = Number of days in season n (d)

U_i, U_{in} = Allowable use of plant group i in season ... (proportion)

... = Variance ...

... = Number of ... during season n ...

... = Maximum allowable number of ... (an)

APPENDIX II

CLASSIFICATION OF RANGE PLANTS:
PROPER USE FACTORS

ORIGIN OF THE TABLE

The material on which this appendix is based was complied in the late 1950's and represents an extensive review of the Proper Use Factor literature to that time. The information from many agency documents and from a few scientific references was complied by G. M. Van Dyne and H. G. Fisser while the former was on the faculty and the latter was a graduate research assistant at Montana State College, Bozeman.

Organization of the Table

Organization of Plants Listings

Plants in the following table are listed alphabetically by Latin name within groups in the following order: grasses, grass-like plants, forbs, and shrubs and trees. In some cases, more than one common name will apply to a particular plant; however, the common name which was used in a majority of the references given was listed in the table. No attempt has been made to update nomenclature from that listed in the original references.

To the left of each scientific plant name, a four-to-eight character alphanumeric name code has been added. These codes were taken from the "National List of Scientific Plant Names, Soil Conservation Service, United States Department of Agriculture" and "Exhibit 407.1(a)(6) NSH Notice 30-3/20/78." In instances where no code is given by either reference, the corresponding space in the table is left blank.

Table Subdivisions

References for three different areas are subdivided in these tables. These three areas are the Great Plains states, Northwest states, and Southwest states. In this geographic subdivision, the Great Plains grouping includes the plains portions of states from Canada to Mexico.

Table Organization of Data

Following the common name and regional characterization, a set of three numbers may be found. The first number refers to the reference number; the second number, the proper use factor for cattle and horses for the forage species involved; and the third number, the proper use factor for sheep and goats for the forage species involved. Thus, many references will be found for some of the more common plants as is indicated in the table. On the far right-hand side of the table is a group of three numbers set off by two vertical lines. The first number here represents the number of references which gave proper use factors for that particular species; the second number, the average proper use factor for cattle and horses; and the third number is the average proper use factor for sheep and goats.

References

The references below were taken from the literature. Within any given reference source there may have been one or more subdivisions based on rainfall belt, season of year, and other characteristics.

REFERENCE LIST

Reference Source	Reference No.	Subdivision
Albee, L R., E. W. Klosterman, W. H. Burkitt, and H. R. Olson. 1948. South Dakota grasslands--their condition and management. S. Dakota Agric. Expt. Sta. Circ. 79.		
	1	Western S. Dakota
	2	Eastern S. Dakota
Bureau of Land Management. 1941. Palatability table for eastern Oregon. (Grazing service--prepared in Region 4 in June 1939, rechecked in 1941.)		
	3	Spring-Fall
	4	Summer
	5	Winter
Bureau of Land Management. 1954. Recommend proper use allowances for principal forage species of southern Idaho and southeastern Oregon for use with weight estimated method of forage inventory.		
	6	Spring-Fall
	7	Summer
Bureau of Land Management. ____. Key forage species southeastern Washington area (Columbia, Garfield, Asotin, Whitman, and Spokane counties)		
	8	12-15" rainfall spring
	9	12-15" rainfall spring-fall
	10	12-15" rainfall summer
	11	12-15" rainfall fall, winter
	12	Forest type 22-30" rainfall spring
	13	Forest type 22-30" rainfall spring-fall
	14	Forest type 22-30" rainfall summer
	15	Forest type 22-30" raingall fall-winter
	16	Foothill type 15-22" rainfall spring
	17	Foothill type 15-22" rainfall spring-fall
	18	Foothill type 15-22" rainfall summer
	19	Foothill type 15-22" rainfall fall-winter
Bureau of Land Management. _____. Key forage species for southeastern Oregon area (Deschutes, Klamath, Lake, Harvey, and Malheur counties)		
	20	Spring
	21	Spring-Fall
	22	Summer
	23	Fall-Winter
Bureau of Land Management. ____. Key forage species of Southcentral Washington area (Kittitas, Yakima, Klickitat counties).		
	24	Spring
	25	Spring-Fall
	26	Summer
	27	Fall-Winter

Reference Source	Reference No.	Subdivision
Carlson, N. K., and M. Garlson. 1948. Range condition--a classification of the timber--browse--grass ranges in the Benewak Soil Conservation Distict, St. Maries, Idaho. USDA Soil Conservation Service, Pacific Coast Region. Multilith		
	28	Level and gentle slope
	29	Steep slopes
Collins, D. F. 1948. Range condition--a classification of the grass sagebrush range in the Owybee Soil Conservation District, Elka, Nevada. USDA Soil Conservation Service, Pacific Coast Region. Multilith		
	30	Excellent condition 0-20% slope
	31	Excellent condition 21-60% slope
	32	Good condition 0-20% slope
	33	Good condition 21-60% slope
	34	Fair condition 0-20% slope
	35	Fair condition 21-60% slope
	36	Poor condition 0-20% slope
	37	Poor condition 21-60% slope
	38	Very poor condition 0-20% slope
	39	Very poor condition 21-60% slope
Everson, A. C., and Ira Clark. 1946. Range condition--a classification of the grassland sagebrush browse, and aspen forage types in the Bear Lake Soil Conservation District. USDA Soil Conservation Service. Multilith		
	40	Excellent condition 0-30% slope
	41	Excellent condition over 30% slope
	42	Good condition 0-30% slope
	43	Good condition over 30% slope
	44	Fair condition 0-30% slope
	45	Fair condition over 30% slope
	46	Poor condition 0-30% slope
	47	Poor condition over 30% slope
	48	Very poor condition 0-30% slope
	49	Very poor condition over 30% slope
	50	Excellent condition 0-30% slope
	51	Excellent condition over 30% slope
	52	Good condition 0-30% slope
	53	Good condition over 30% slope
	54	Fair condition 0-30% slope
	55	Fair condition over 30% slope
	56	Poor condition 0-30% slope
	57	Poor condition over 30% slope
	58	Very poor condition 0-30% slope
		Very poor condition over 30% slope
	59	Excellent condition 0-30% slope
	60	Excellent condition over 30% slope
	61	Good condition 0-30% slope
	62	Good condition over 30% slope
	63	Fair condition 0-30% slope
	64	Fair condition over 30% slope
	65	Poor condition 0-30% slope
	66	Poor condition over 30% slope
	67	Very poor condition 0-30% slope
	68	Very poor condition over 30% slope

Reference Source	Reference No.	Subdivision
Forage Plants Division. ____. One hundred percent density yields, symbols, and utilization percentages of 506 plant species. Dominion Experiment Station, Swift Current, Sask., Canada.		
	69	
Forest Service. 1941. List of standard symbols, common names, and proper use factors for plants of Region 1. In Range Management Handbook--Region 1. pp. 801-850		
	70	
Forest Service. 1950. Plant use factors for eastern Oregon and eastern Washington. Pacific Northwest Forest and Range Experiment Station and Region 6.		
	71	
Heidenreich, V. T., and Ina Clark. 1946. Range condition--a classification of the grassland, sagebrush, browse, and aspen forage types in the Portneuf Soil Conservation District. USDA Soil Conservation Service Pacific Coast Region.		
	72	Excellent condition 0-30% slope
	73	Excellent condition over 30% slope
	74	Good condition 0-30% slope
	75	Good condition over 30% slope
	76	Fair condition 0-30% slope
	77	Fair condition over 30% slope
	78	Poor condition 0-30% slope
	79	Poor condition over 30% slope
	80	Very poor condition 0-30% slope
		Very poor condition over 30% slope
	81	Excellent condition 0-30% slope
	82	Exelent condition over 30% slope
	83	Good condition 0-30% slope
	84	Good condition over 30% slope
	85	Fair condition 0-30% slope
	86	Fair condition over 30% slope
	87	Poor condition 0-30% slope
	88	Poor condition over 30% slope
	89	Very poor condition 0-30% slope
	90	Very poor condition over 30% slope
	91	Excellent condition 0-30% slope
	92	Excellent condition over 30% slope
	93	Good condition 0-30% slope
	94	Good condition over 30% slope
	95	Fair condition 0-30% slope
	96	Fair condition over 30% slope
	97	Poor condition 0-30% slope
	98	Poor condition over 30% slope
	99	Very poor condition 0-30% slope
	100	Very poor condition over 30% slope
Interagency Range Committee. 1941. Proper use factor table, Nevada District Number 1.		
	101	Summer
	102	Spring-Fall
	103	Winter

Reference Source	Reference No.	Subdivision
Interagency Range Committee. 1940. Palatability table for southern Idaho. Soil Conservation Service Region 9.		
	104	Spring-Fall
	105	Winter
	106	Summer
Interagency Range Committee. 1942. Proper use tables for browse--timber areas of northern Idaho.		
	107	
Interagency Range Committee. ____. Proper use table for the lower foothills and plains of Montana.		
	108	
Soil Conservation Service. 1941. Range Plant check list for the Pacific Southwest Region. Range Conservation Division, Berkeley, California.		
	109	
Swanson, R. E. 1947. Range condition, a classification of the sand-bunchgrass range in the West Umatilla Soil Conservation District. USDA Soil Conservation Service, Pacific Coast Region.		
	110	Excellent condition spring-fall
	111	Excellent condition fall-winter
	112	Good condition spring-fall
	113	Good condition fall-winter
	114	Fair condition spring-fall
	115	Fair condition fall-winter
	116	Poor condition spring-fall
	117	Poor condition fall-winter
	118	Very poor condition spring-fall
	119	Very poor condition fall-winter

PROPER USE FACTORS

GRASSES

SCS Plant Code	r=reference c=cattle and horses; s=sheep and goats		Reg.	r	c	s	r	c	s	r	c	s	No.	Aver. c	s
AGRØP2	AGROPYRON	WHEATGRASS	SW	109	20	70	101	65	40	102	65	65			
				103	50	60							4	50	59
			NW	3	70	40	4	60	40	5	60	50			
				107	60	40	104	70	40	105	65	60			
				106	65	40	71	50	20	40	65	40			
				41	30	20	42	65	40	43	30	20			
				44	55	35	45	27	17	46	45	25			
				47	22	12	48	35	20	49	17	12			
				50	65	40	51	30	20	52	65	40			
				53	30	20	54	55	35	55	27	17			
				56	45	25	57	22	12	58	35	20			
				59	65	40	60	30	20	61	65	40			
				62	30	20	63	55	35	64	27	17			
				65	45	25	66	22	12	67	35	20			
				68	17	12	72	65	40	73	30	20			
				74	65	40	75	30	20	76	55	35			
				77	27	17	78	45	25	79	22	12			
				80	35	20	81	17	12	82	65	40			
				83	30	20	84	55	35	85	27	17			
				86	45	25	87	22	12	88	35	20			
				89	17	12	90	65	40	91	30	20			
				92	65	40	93	30	20	94	55	35			
				95	27	17	96	45	25	97	22	12			
				98	35	20	99	17	12	100	65	40			
				28	65	40	29	30	20				68	43	26
AGAL	A. albicans	Montana wheatgrass	GP	69	50	40							1	50	40
			NW	70	80	50							1	80	50
AGBA2	A. bakeri	Baker wheatgrass		70	80	50							1	80	50
	A. canimum	Bearded wheatgrass		70	80	50							1	80	50
AGCR	A. cristatum	Crested wheatgrass	SW	109	80	80	101	75	75	102	80	60			
				103	50	70							4	71	71
			GP	108	70	50	69	70	50	1	70	50			
				2	70	50							4	70	50
			NW	3	70	60	4	70	60	5	70	60			
				107	60	30	104	70	50	105	80	70			
				106	75	60	8	40	40	9	70	40			
				24	30	40	25	70	40	26	50	20			
				27	60	40	20	40	30	21	70	40			
				23	70	40	6	50	40	7	40	20			
				71	40	25	70	80	50				20	60	43
AGDA	A. dasystachyum	Thickspike wheat-grass	SW	109	60	50	101	65	65	102	65	40			
				103	50	60							4	60	54
			GP	108	70	50	69	55	40				2	62	45
			NW	3	60	50	4	60	40	5	60	60			
				6	50	50	7	40	30	71	50	30			
				70	80	50	104	65	40	105	65	60			
				106	60	40							10	59	45
AGGR3	A. griffithsi	Griffiths wheatgrass		70	80	50							1	80	50
AGIN	A. inerme	Beardless wheatgrass		3	70	40	4	65	40	5	60	40			
				6	50	40	7	40	20	20	40	30			

AGIN	A. inerme	Beardless wheatgrass		21 70 40	22 60 20	23 70 40	
				24 40 30	25 70 40	26 60 20	
				27 70 40	70 80 50	104 70 40	
				106 65 40	107 55 50		17 61 36
AGLA2	A. latiglume	Alpine wheatgrass		70 80 50			1 80 50
	A. pauciflorum	Slender wheatgrass	SW	101 75 75	102 75 50	103 60 70	
				109 70 40			4 70 59
			GP	1 70 50	2 70 50	69 55 40	
				108 70 50			4 66 48
			NW	3 70 50	4 70 50	5 70 50	
				22 70 35	26 70 35	70 80 50	
				71 50 30	104 70 50	105 75 70	
				106 70 50	107 60 40		11 69 46
AGRE2	A. repens	Quackgrass	SW	109 60 30			1 60 30
			GP	2 60 40			1 60 40
			NW	3 60 30	4 60 30	5 60 30	
				6 50 40	7 30 20	70 80 50	
				71 50 20	104 60 30	107 60 30	9 57 31
AGRI	A. riparium	Streambank wheat-grass		3 65 35	5 50 20	6 50 40	
				7 20 20	70 80 50	104 65 35	
				106 60 40			7 56 34
AGSA2	A. saxicola	Foxtail wheatgrass		3 70 50	4 70 50	5 70 50	3 70 50
AGSC4	A. scribneri	Scribner wheatgrass		70 80 50			1 80 50
AGSM	A. smithii	Western wheatgrass	SW	101 70 60	102 65 50	103 45 55	
				109 70 50			4 62 54
			GP	1 70 50	2 70 50	69 55 40	
				108 80 50			4 69 48
			NW	3 60 40	4 60 40	5 60 40	
				6 50 50	7 30 20	20 30 20	
				21 60 40	22 60 40	23 50 30	
				70 80 50	71 50 30	104 60 40	
				105 60 50	106 65 40		14 55 38
AGSP	-A. spicatum	Bluebunch wheatgrass	SW	101 80 70	102 70 50	103 40 55	
				109 70 50			4 55 59
			GP	108 50 30			1 50 30
			NW	3 20 50	4 70 50	5 70 50	
				6 50 40	7 40 20	8 40 30	
				9 70 40	10 60 20	11 70 40	
				12 40 30	13 70 40	14 60 20	
				15 70 40	16 40 30	17 70 40	
				18 60 20	19 70 40	20 40 30	
				21 70 40	22 60 20	23 70 40	
				24 40 30	25 70 40	26 60 20	
				27 70 40	70 80 50	71 50 20	
				104 70 40	105 70 65	106 70 50	
				107 60 50	110 60 70	111 60 30	
				112 55 65	113 55 30	114 50 50	
				115 45 30	116 40 10	117 35 20	
				118 25	119 25 15		41 55 37
AGSU	A. subsecundum	Bearded wheatgrass	SW	101 65 55	102 60 50	103 35 55	
				109 60 50			4 55 52
			GP	69 30 40			1 30 40
			NW	3 50 35	4 60 50	5 60 50	
				70 80 50	71 55 35	104 55 35	

PROPER USE FACTORS GRASSES (cont.)

AGSU	A. subsecundum	Bearded wheatgrass	NW	105 60 55	106 65 50		2 62 52
AGTR3	A. triticeum	Annual wheatgrass		70 80 50			1 80 50
AGRØS2	AGROSTIS	BENTGRASS	SW	101 75 70	107 70 40	103 35 45	
				109 70 50			4 62 51
			NW	3 60 30	4 70 40	5 70 40	
				22 70 20	104 60 30	105 70 45	
				106 75 40	107 20 10		8 62 32
AGAL3	A. alba	Redtop	SW	109 70 60			1 70 60
			GP	108 80 50			1 80 50
			NW	3 70 30	4 70 30	5 70 30	
				70 80 50	71 50 20	104 70 30	
				106 75 40	107 60 30		8 68 32
AGDI	A. diegoensis	Thin bentgrass	SW	109 60 50			1 60 50
			NW	70 80 50	71 35 20		2 58 35
AGEX	A. exarata	Spike bentgrass	SW	109 70 60			1 70 60
			GP	108 80 50			1 80 50
			NW	3 70 40	4 70 40	5 70 40	
				70 80 50	71 50 20	104 70 40	
				107 60 30			7 67 37
AGHU	A. humilis	Ticklegrass		70 80 50			1 80 50
	A. hiemalis	Winter bentgrass	SW	101 75 60	102 70 40	103 40 50	
				109 60 40			4 61 46
			GP	108 50 30			1 50 30
			NW	3 60 40	4 50 40	5 70 50	
				70 80 50	71 40 20	104 60 40	
				105 70 50	106 50 40	107 20 10	9 56 38
	A. interrupta	Italian windgrass		70 80 50			1 80 50
AGIC	A. idahoensis	Idaho redtop		70 80 50			1 80 50
AGØR	A. oregonensis	Oregon redtop		70 80 50			1 80 50
	A. pallens	Dune bentgrass	SW	109 60 40			1 60 40
			NW	70 80 50			1 80 50
	A. palustris	Creeping bentgrass	SW	101 80 70	102 70 40	103 45 60	
				109 70 40			4 66 52
			NW	3 70 40	4 80 60	5 70 60	
				70 80 50	104 70 40	105 70 60	
				106 80 60			7 74 53
AGRØ4	A. rossae	Ross bentgrass		70 80 50	71 50 30		2 65 40
AGSC5	A. scabra	Bentgrass		69 0 0			1 0 0
	A. stolonifera	Bentgrass		69 35 40			1 35 40
AGTH	A. thurberiana	Thurber redtop		70 80 50			1 80 50
AIRA+	AIRA	HAIRGRASS		109 20 30			1 20 30
AICA	A. caryophyllea	Silver hairgrass		109 20 30			1 20 30
ALOPE	ALOPECURUS	FOXTAIL		109 80 60			1 80 60
ALAE	A. aequalis	Shortawn foxtail	SW	109 80 60			1 80 60
			GP	69 55 40			1 55 40
			NW	3 70 40	4 60 30	5 60 30	
				70 80 70	104 70 40		5 68 42
	A. agrestis	Mountain foxtail		101 80 60			1 80 60
AIAI2	A. alpinus	Alpine foxtail	SW	109 80 60			1 80 60
			NW	70 80 70			1 80 70
AICA4	A. carolinianus	Carolina foxtail		70 80 70			1 80 70
AIGE2	A. geniculatus	Water foxtail	GP	69 55 40			1 55 40
			NW	70 80 70			1 80 70
AIPA4	A. pallescens	Washington foxtail		70 80 70			1 80 70

PROPER USE FACTORS GRASSES (cont.)

AIPR3	A. pratensis	Shortawn foxtail		107 30 20	70 80 70		2 55 45
	AMMOPHILA Arenaris	EUROPEAN BEACHGRASS		109 10 10			1 10 10
ANGE	ANDROPOGON Gerardi	BIG BLUE STEM	SW	109 60 60			1 60 60
	furcatus		GP	1 70 50	2 70 50	108 70 40	
				69 40 30			4 62 42
			NW	70 80 50			1 80 50
ANHA	A. hallii	Sand bluestem	SW	109 40 30			1 40 30
			GP	1 40 30			1 40 30
ANSA	A. saccharoides	Silver bluestem		109 40 30			1 40 30
ANSC2	A. scoparius	Little bluestem		1 20 10	2 70 50	69 20 10	
				108 20 10			4 32 20
	ANTHOXANTHUM aristatum	ANNUAL VERNALGRASS		109 40 40			1 40 40
ANOD	A. odoratum	Sweet vernalgrass		109 50 40			1 50 40
ARIST	ARISTIDA	THREEAWN	SW	101 50 35	102 25 40	103 10 20	
				109 20 10			4 26 26
			GP	108 20 10			1 20 10
			NW	104 35 10	105 20 10	106 50 40	3 35 20
ARFE4	A. fendleriana	Fender threeawn	SW	101 40 30	102 20 40	103 10 20	
				109 30 20			4 25 28
			NW	70 10 10			1 10 10
ARLO3	A. longiseta	Red threeawn	SW	101 60 35	102 25 40	103 10 20	
				104 20 10			4 29 26
			GP	1 20 10	69 20 10		2 20 10
			NW	3 35 20	4 20 25	5 20 10	
				70 10 10	104 35 20	105 20 10	
				106 20 25			7 23 17
ARO2	A. oligantha	Prairie threeawn		109 30 20			1 30 20
AREL3	ARRHENATHERUM elatius	TALL OATGRASS	SW	109 60 60			1 60 60
			NW	3 40 30	4 40 30	70 80 60	
				104 40 30			4 50 38
AVENA	AVENA	OAT		109 80 70			1 80 70
AVBA	A. barbata	Slender oat		109 70 60			1 70 60
AVFA	A. fatua	Wildoat	SW	109 80 70			1 80 70
			NW	3 70 40	4 70 40	5 70 40	
				6 40 20	7 40 0	70 80 60	
				104 70 40	107 70 40		8 64 35
	A. hookeri	Spike oatgrass	GP	69 55 55			1 55 55
			NW	70 80 60			1 80 60
	BECKMANNIA erucaeformis	EUROPEAN SLOUGHGRASS		109 40 30			1 40 30
BESY	B. syzigachne	American sloughgrass	SW	101 0 50	103 10 0	109 50 10	3 20 20
			GP	69 55 20	108 40 30		2 48 25
			NW	3 40 30	4 40 30	5 40 30	
				70 70 30	104 40 30	107 50 20	6 47 28
BLKI	BLEPHARIDACHNE Kingii	KING DESERTGRASS		101 20 20	102 35 30	103 15 35	
				109 30 30			4 25 29
BOUTE	BOUTELOUA	GRAMA GRASS		101 75 70	102 75 75	103 50 40	3 67 62
BOAR	B. aristoides	Needle grama		109 60 50			1 60 50
BOBA2	B. barbata	Six weeks grama		109 60 50			1 60 50
BOCU	B. curtipendula	Side oats grama	SW	101 70 65	102 70 50	103 40 50	
				109 70 60			4 62 56
			GP	1 70 50	2 70 50	108 70 50	3 70 50
			NW	70 80 80			1 80 80
BOER4	B. eriopoda	Black grama		109 70 60			1 70 60
BOFI	B. filiformis	Slender grama		109 80 70			1 80 70

PROPER USE FACTORS — GRASSES (cont.)

BOGR2	B. gracilis	Blue grama	SW	101 80 70	102 80 50	103 40 15	
				109 70 60			4 68 49
			GP	1 80 70	2 80 70	69 55 55	
				108 80 80			4 74 69
			NW	70 80 80			1 80 80
BOHI2	B. hirsuta	Hairy grama	SW	109 80 80			1 80 80
			GP	1 80 70			1 80 70
BORO2	B. rothrockii	Rothrock grama		109 30 20			1 30 20
BRMA	BRIZA maxima	BIG QUACKING GRASS		109 20 20			1 20 20
BRMI2	B. minor	Little quacking grass		109 20 20			1 20 20
BROMU	BROMUS	BROME	SW	101 65 75	102 55 30	103 45 40	
				109 60 40			4 56 46
			NW	3 60 40	4 60 40	5 60 40	
				104 60 40	106 60 40	71 40 30	6 57 38
	BROMUS (annual)	ANNUAL BROMEGRASS		3 40 30	4 20 20	5 40 40	
				6 20 10	7 30 10	71 5 5	
				104 40 30	106 15 15		8 26 20
BRAN	B. anomalus	Nodding brome	SW	101 75 70	102 0 35	103 50 0	
				109 50 40			4 44 36
			GP	108 20 20			1 20 20
			NW	3 60 40	4 75 35	5 60 40	
				70 80 50	104 60 40	106 75 30	6 68 39
BRAR3	B. arenarius	Australian brome		109 30 20			1 30 20
BRBR4	B. breviaristatus	Slimleaf brome		70 80 50			1 80 50
BRBR5	B. brizaeformis	Rattle brome	SW	109 20 20	101 0 60		2 10 40
			NW	3 40 30	4 20 20	5 40 40	
				70 20 20	104 40 30	105 40 40	
				106 20 20			7 31 29
BRMA4	B. marginatus	Mountain brome	SW	101 75 75	102 75 35	103 45 45	
				109 70 50			4 66 51
			GP	108 70 50			1 70 50
			NW	3 70 40	4 75 35	5 75 45	
				6 50 40	7 40 30	22 60 30	
				26 35 30	70 80 50	71 30 20	
				104 70 40	105 75 45	106 75 35	
				107 70 60			
BRCI2	B. ciliatus	Fringed brome	GP	69 55 55			1 55 55
			NW	70 80 50	71 60 30		2 70 40
BRCA6	B. catharticus	Rescue brome		109 50 40			1 50 40
BRCO4	B. commutatus	Hairy brome	SW	109 60 50			1 60 50
			NW	70 80 50			1 80 50
BRIN2	B. inermis	Smooth brome	SW	101 80 80	102 70 40	103 35 40	
				109 80 60			4 66 55
			GP	1 80 50	2 80 50	69 80 55	
				108 70 50			4 78 51
			NW	3 80 40	4 80 40	5 70 40	
				107 60 50	104 80 40	105 70 40	
				106 80 40	70 80 50		8 99 42
BRJA	B. japonicus	Japanese brome	SW	101 0 60	109 40 30		2 20 45
			GP	108 20 20			1 20 20
			NW	3 40 30	4 40 15	5 40 40	
				104 40 30	105 40 40	106 40 15	6 40 28
BRLA3	B. laevipes	Chinook brome		109 60 50			1 60 50
BRMA3	B. madritensis	Spanish brome		109 40 40			1 40 40

PROPER USE FACTORS — GRASSES (cont.)

BRMO2	B. mollis	Soft brome	SW	101 0 50	109 50 40		2 30 45
	(hordeaceous)		NW	3 40 30	104 40 30		2 40 30
	B. orcuttianus	Orcutt brome		109 60 40			1 60 40
BRRA2	B. racemous	Bald brome	SW	109 70 60			1 70 60
			NW	3 40 30	104 40 30		2 40 30
BRRI	B. rigidus	Ripgut brome		109 30 20			1 30 20
BRRV2	B. rubens	Foxtail brome	SW	101 0 50	109 40 10		2 20 30
			NW	3 30 20	4 10 10	5 30 10	
				104 30 20	105 25 10	106 5 5	6 22 12
BRSE	B. secalinus	Chess brome	SW	109 20 10			1 20 10
			NW	70 20 20			1 20 20
BRST2	B. sterilis	Poverty brome		109 30 20			1 30 20
BRTE	B. tectorum	Cheatgrass brome	SW	101 10 75	102 40 15	103 75 40	
				109 20 20			4 36 38
			GP	108 20 20			1 20 20
			NW	3 40 30	4 20 20	5 40 40	
				6 20 10	7 30 10	20 10 30	
				21 40 30	22 20 5	23 30 20	
				24 20 30	25 20 30	26 10 10	
				27 20 20	70 20 20	71 5 5	
				104 40 30	105 40 40	106 15 15	
				107 10 10			19 25 19
	B. trinii	Chilean brome		109 30 30			1 30 30
BRVU	B. vulgaris	Columbia brome	SW	109 50 30			1 50 30
			NW	70 80 50			1 80 50
BUDA	BUCHLOE dactyloides	BUFFALOGRASS	SW	101 75 75	102 75 70	103 70 70	
				109 70 60			4 72 69
			GP	1 80 80	2 80 80	108 80 80	3 80 80
			NW	70 80 80			1 80 80
CALAM	CALAMAGROSTIS	REEDGRASS	SW	101 25 30	102 5 20	103 20 0	
				109 40 20			4 22 18
			NW	3 30 20	4 30 20	14 10 10	
				104 30 20	105 5 0	106 25 20	
				107 20 20			7 21 16
CACA4	C. canadensis	Bluejoint reedgrass	SW	101 40 60	102 0 20	103 30 0	
				109 50 30			4 30 28
			GP	69 10 10			1 10 10
			NW	70 70 60	71 50 10	104 50 30	
				106 50 20	107 50 20		5 54 28
CAIN	C. inexpansa	Northern reedgrass		69 20 20			1 20 20
CAMO	C. montanensis	Plains reedgrass	SW	101 35 50	102 30 20	103 25 10	3 30 27
			GP	69 55 55	108 50 30		2 52 42
			NW	3 50 30	4 35 20	5 30 10	
				104 50 30	105 30 10	106 35 20	6 38 20
CARU	C. rubescens	Pinegrass	SW	109 20 10	101 15 15	102 0 20	
				103 15 0			4 12 11
			GP	108 30 20			1 30 20
			NW	3 15 15	4 20 10	22 10 10	
				26 20 10	70 30 20	71 10 10	
				104 15 15	106 20 10	107 30 10	9 19 12
CASC2	C. scribneri	Scribner reedgrass		70 70 60			1 70 60
CALO	CALAMOVILFA longifolia	PRAIRIESAND REED	GP	1 20 10	2 20 10	69 20 10	
				108 20 10			4 20 10
			NW	3 10 10	70 0 0	104 10 10	3 7 7

PROPER USE FACTORS GRASSES (cont.)

CAAQ3	CATABROSA aquatica	BROOKGRASS	SW	101 0 60	103 60 0	109 40 30	3 40 37
			GP	69 20 10			1 20 10
			NW	3 50 30	4 60 40	5 40 20	
				104 50 30	105 40 20	106 60 50	6 50 32
CEPA7	CENCHRUS pauciflorus	FIELD SANDSPUR		3 0 0	104 0 0		2 0 0
CILA2	CINNA latifolia	DROOPING WOODREED		70 80 60			1 80 60
CYDA	CYNODON dactylon	BERMUDA GRASS		101 0 60	103 80 0	109 80 60	3 53 53
CYEC	CYNOSURUS echinatus	HEDGEHOG DOGTAIL		109 10 10			1 10 10
DAGL	DACTYLIS glomerata	ORCHARD GRASS	SW	101 70 70	102 60 20	103 30 15	
				109 70 60			4 58 41
			NW	3 70 30	4 70 20	5 60 15	
				104 70 30	105 60 15	106 60 20	
				6 50 50	7 40 30	70 80 60	
				71 70 40	107 70 60		
DANTH	DANTHONIA	OATGRASS		101 60 60	102 60 40	102 35 30	3 52 43
DACA3	D. californica	California danthonia	SW	109 70 50			1 70 50
			GP	69 55 55			1 55 55
			NW	3 70 30	4 70 30	6 50 50	
				7 20 20	70 70 50	71 60 30	
				104 70 30	107 50 30		8 59 34
DAIN	D. intermedia	Timber oatgrass	GP	1 50 20	69 25 25		2 28 22
			NW	70 70 50	71 60 30		2 65 40
DAPA2	D. parryi	Parry oatgrass	GP	69 55 55			1 55 55
			NW	70 70 50			1 70 50
DASP2	D. spicata	Poverty oatgrass		70 70 50			1 70 50
DAUN	D. unispicata	One spike danthonia	SW	101 60 60	102 60 40	103 35 20	
				109 60 40			4 54 40
			GP	69 20 10			1 20 10
			NW	3 65 40	4 60 40	5 60 20	
				70 70 50	71 50 30	104 65 35	
				105 50 20	106 60 40	107 50 30	9 61 31
DESCH	DESCHAMPSIA	HAIRGRASS	SW	101 55 55	102 40 35	103 35 20	3 43 37
			GP	108 40 20			1 40 20
			NW	3 40 20	4 70 40	5 40 20	
				104 40 20	105 40 20	106 70 40	6 50 53
DEAT	D. atropur purea	Mountain hairgrass		70 80 40			1 80 40
DECA5	D. caespitosa	Tufted hairgrass	SW	101 55 55	102 0 30	103 25 0	
				109 70 50			4 38 34
			GP	69 55 55			1 55 55
			NW	3 55 25	4 55 30	22 70 55	
				25 70 55	70 80 40	71 50 55	
				104 55 25	106 55 30	107 50 0	9 60 35
DEDA	D. danthonioides	Annual hairgrass	SW	101 30 40	102 5 20	103 20 0	
				109 40 40			4 38 25
			NW	3 30 20	4 30 20	5 10 0	
				70 80 40	71 0 0	104 30 20	
				105 5 0	106 30 20		8 27 15
DEEL	D. elongata	Slender hairgrass	SW	101 60 60	102 50 35	103 40 20	
				109 70 50			4 55 41
			NW	3 30 40	4 60 35	5 50 20	
				70 80 40	71 10 5	104 60 40	
				105 50 20	106 60 35	107 10 0	9 40 26
DEHO	D. holciformis	Pacific hairgrass		109 30 30			1 30 30

PROPER USE FACTORS GRASSES (cont.)

DIGIT2	DIGITARIS	CRABGRASS		109 50 50			1 50 50
DISA	D. sanguinalis	Hairy crabgrass		109 50 50			1 50 50
DISTI	DISTICHLIS	SALTGRASS		101 45 45	102 40 30	103 30 35	
				109 50 40			4 41 38
	D. dentata	Little saltgrass	SW	101 30 35	102 30 30	103 25 30	
				109 40 30			4 31 31
			NW	3 40 20	4 30 20	5 30 30	
				104 40 20	105 30 30	106 30 20	6 33 23
DISP	D. spicata	Seashore saltgrass	SW	101 45 45	102 40 30	103 30 35	
				109 50 40			4 41 38
			NW	70 20 10	104 40 20	105 45 35	
				106 25 20			4 32 21
DIST	D. stricta	Inland saltgrass	SW	101 50 45	102 45 30	103 30 35	
				109 40 30			4 41 35
			GP	1 20 10	2 20 10	108 20 10	3 20 10
			NW	3 40 20	4 25 20	5 45 35	
				6 40 30	7 20 20	107 20 10	6 32 22
ECHIN4	ECHINOCHLA	COCKSPUR		109 30 20			1 30 20
ECCR	E. crusgalli	Barnyard grass	SW	101 0 30	103 15 0	109 30 20	3 15 17
			NW	3 60 30	4 60 30	70 80 60	3 67 40
ELYMU	ELYMUS	WILDRYE	SW	101 50 50	102 50 40	103 40 35	
				109 50 50			4 48 44
			NW	3 50 40	4 50 40	5 50 40	
				104 50 40	105 50 35	106 50 40	6 50 39
ELCA4	E. canadensis	Canada Wildrye	SW	101 45 45	102 50 30	103 30 50	
				109 40 40			4 41 41
			GP	1 30 30	2 30 30	69 30 30	
				108 30 20			4 30 28
			NW	3 50 30	4 45 30	5 50 50	
				6 30 20	7 20 20	70 40 20	
				104 50 30	105 50 50	106 45 30	9 42 31
	E. caput medusae	Medusahead wildrye		109 20 20			1 20 20
ELCO4	E. cinereus	Giant wildrye	SW	109 40 10			1 40 10
			GP	108 10 0			1 10 0
ELCO4	E. condensatus	Giant wildrye	SW	101 50 50	102 50 40	103 40 35	3 47 42
			NW	3 60 40	4 50 40	5 70 30	
				6 30 10	7 10 10	20 25 10	
				21 50 20	22 40 10	23 60 10	
				70 10 5	71 40 10	104 60 10	
				105 70 30	106 50 40		
ELFL2	E. flavescens	Yellow wildrye	SW	101 35 40	102 45 40	103 30 35	
				109 40 30			4 38 36
			NW	3 40 20	4 35 40	5 45 40	
				104 40 20	105 45 35	106 33 40	6 40 32
ELGL	E. glaucus	Blue wildrye	SW	101 50 50	102 60 40	103 35 40	
				109 40 20			4 49 36
			NW	3 50 40	4 50 40	5 60 40	
				6 40 20	7 35 20	70 40 10	
				71 40 20	104 50 35	105 60 40	
				106 50 40	107 50 30		
ELMA	E. maccunii	Maccun wildrye		69 35 35			1 35 35
ELSA	E. salina	Salina wildrye		101 40 45	102 35 40	103 40 25	
				109 40 30			4 39 35
ELTR3	E. triticoides	Creeping wildrye	SW	101 50 50	102 50 40	103 30 30	

PROPER USE FACTORS GRASSES (cont.)

ELTR3	E. triticoides	Creeping wildrye	SW	109 50 40			1 45 40
			NW	3 70 40	4 50 40	5 50 30	
				6 40 40	7 40 20	20 30 20	
				21 60 40	22 60 40	23 50 30	
				71 50 20	104 70 40	105 50 30	
				106 50 40			
ERAGR	ERAGROSTIS	LOVEGRASS	SW	101 25 25	102 20 20	103 15 10	
				109 20 10			4 20 16
			NW	3 30 30	4 30 20	5 20 10	
				104 30 30	105 20 10	106 25 20	6 26 20
EROR	E. orcuttiana	Orcutt lovegrass		109 20 10			1 20 10
ERPI2	E. pilosa	India lovegrass		109 20 10			1 20 10
	E. pectinacea	Carolina lovegrass		109 20 10			1 20 10
FESTU	FESTUCA	PERENNIAL FESCUE	SW	101 70 70	102 55 50	103 50 45	
				109 70 50			4 61 54
			NW	3 60 40	4 60 40	28 55 55	
				29 27 27	104 60 40	106 60 40	
				107 60 40			7 55 40
FESTU	FESTUCA	ANNUAL FESCUE	SW	109 30 20			1 30 20
			NW	3 20 20	4 70 50	5 55 45	
				104 20 20	105 55 45	106 70 50	
				107 10 10			7 43 34
	F. arida	Desert fescue		104 20 20			1 20 20
FEAR2	F. arizonica	Arizona fescue		109 30 30			1 30 30
FECA	F. californica	California fescue		109 30 30			1 30 30
FEDE	F. dertonensis	Brome fescue	SW	109 20 20			1 20 20
			NW	3 20 20	104 20 20		2 20 20
FEEL	F. elatior	Meadow fescue	SW	101 75 75	102 70 40	103 40 35	
				109 70 40			4 64 48
			NW	3 70 40	4 70 60	104 70 40	
				106 70 60	70 80 60		5 72 52
	F. elatior--var. arundinacea	Reed fescue		3 70 40	4 70 40	104 70 40	3 70 40
FEID	F. idahoensis	Idaho fescue	SW	101 80 80	102 80 60	103 70 70	
				109 80 80			4 78 68
			GP	69 55 55	108 70 50		2 62 52
			NW	3 60 40	4 60 40	5 80 70	
				107 60 50	104 60 40	105 80 70	
				106 60 40	8 35 35	9 60 50	
				10 50 20	11 60 50	12 35 35	
				13 60 50	14 50 20	15 60 50	
				16 35 35	17 60 50	18 50 20	
				19 60 50	24 35 35	25 60 50	
				26 50 20	27 60 50	20 40 30	
				21 60 50	22 50 20	23 60 50	
				6 40 40	7 40 40	71 40 20	
				70 60 60	40 55 55	41 30 27	
				42 55 55	43 27 27	44 50 45	
				45 25 22	46 40 35	47 22 20	
				48 35 35	49 17 20	30 60 30	
				32 40 20	34 30 15	36 25 15	
				38 20 10	50 55 55	51 30 27	
				52 55 55	53 27 27	54 50 45	
				55 25 22	56 40 35	57 22 20	

PROPER USE FACTORS GRASSES (cont.)

FEID	F. idahoensis	Idaho fescue	IW	58 35 35	59 55 55	60 30 27	
				61 55 55	62 27 27	63 50 45	
				64 25 22	65 40 35	66 22 20	
				67 35 35	68 17 20	72 55 55	
				73 30 27	74 55 55	75 27 27	
				76 50 45	77 25 22	78 40 35	
				79 22 20	80 35 35	81 55 55	
				82 30 27	83 55 55	84 27 27	
				85 50 45	86 25 22	87 40 35	
				88 22 20	89 35 35	90 17 20	
				91 55 55	92 30 27	93 55 55	
				94 27 27	95 50 45	96 25 22	
				97 40 35	98 22 20	99 35 35	
				100 17 20			
	F. kingii	Spike fescue	SW	109 50 40			1 50 40
			IW	70 80 60			1 80 60
FEME	F. megalura	Foxtail fescue		109 30 20			1 30 20
FEMY	F. myuros	Rattail fescue		109 20 20			1 20 20
FEOC	F. occidentalis	Western fescue		107 40 10	70 10 10		2 25 10
FEOC2	F. octoflora	Sixweeks fescue	SW	101 35 40	102 40 40	103 35 25	
				109 30 20			4 35 31
			GP	69 10 20	108 10 10		2 10 15
			IW	3 20 20	4 35 40	5 40 25	
				70 10 10	104 20 20	105 40 25	
				106 35 40			7 29 26
FEOV	F. ovina	Sheep fescue	SW	101 80 80	102 90 60	103 70 75	
				109 60 40			4 78 64
			GP	69 55 55			1 55 55
			IW	6 40 40	7 40 40	70 80 80	
				71 50 40			4 52 50
FEOVB	F. ovina--var. brachyphylla	Alpine fescue		3 60 40	4 70 60	104 60 40	
				105 70 60			4 65 50
FERE	F. reflexa	Twoflower fescue		109 20 20			1 20 20
FERU2	F. rubra	Red fescue	SW	109 70 40			1 70 40
			IW	71 30 30			1 30 30
FESC	F. scabrella	Rough fescue	GP	69 55 55	108 70 50		2 62 52
			IW	70 80 50	107 70 30		2 75 40
FESU	F. subulata	Bearded fescue	SW	109 70 50			1 70 50
			IW	70 80 60			1 80 60
FETH	F. thurberi	Thurber fescue		70 80 60			1 80 60
FEVI	F. viridula	Green fescue	SW	109 70 50			1 70 50
			IW	22 50 50	70 60 60	71 50 50	3 60 53
	FLUMINEA festucacea	RIVERGRASS		69 55 55			1 55 55
GAVE3	GASTRIDIUM ventricosum	NIT GRASS		109 30 20			1 30 20
GLYCL	GLYCERIA	MANNAGRASS	SW	101 60 60	102 50 30	103 25 20	
				109 60 50			4 51 40
			IW	3 60 30	4 60 30	5 60 20	
				71 60 30	104 60 30	105 60 20	
				106 60 30	107 60 30		8 60 28
GLGR	G. grandis	American mannagrass		69 30 30			1 30 30
GLST	G. striata	Fowl mannagrass	SW	101 60 60	102 60 30	103 25 20	
				109 60 50			4 51 40
			GP	69 20 20			1 20 20

PROPER USE FACTORS — GRASSES (cont.)

GLST	G. striata	Fowl mannagrass	IM	3 50 30	4 50 30	5 50 20	
				104 60 30	105 60 20	106 60 30	6 60 27
HEKI	HESPEROCHLOA kingii	SPIKE FESCUE		101 45 45	102 50 40	103 30 35	
				109 50 40			4 44 30
	HETEROPOGON contortus	TANGLEHEAD		109 10 10			1 10 10
HIOD	HIEROCHLOE odorata	SWEETGRASS		69 20 10			1 20 10
HIJA	HILARIA jamesii	GALLETA	SW	101 50 65	102 20 40	103 35 55	
				109 60 40			4 54 50
HIRI	H. rigida	Big galleta		109 60 40			1 60 40
HOLA	HOLCUS lanatus	COMMON VELVET GRASS		109 50 30			1 50 30
HORDE	HORDEUM	BARLEY	SW	101 25 30	102 35 20	103 20 30	
				109 30 30			4 28 28
			IM	3 30 20	4 25 20	5 35 30	
				71 20 10	104 30 20	105 35 20	
				106 25 20			7 29 20
HOBR2	H. brachyantherum	Meadow barley	SW	101 30 30	102 35 25	103 20 25	
				109 30 30			4 29 28
			GP	108 30 20			1 30 20
			IM	3 40 30	4 30 20	5 35 25	
				71 40 30	104 40 30	105 35 25	
				106 30 20			7 36 25
	H. gussoneanum	Mediterranean barley	SW	109 30 20			1 30 20
			IM	70 40 10			1 40 10
HOSU	H. jubatum	Foxtail barley	SW	101 20 25	102 30 15	103 20 30	
				109 30 30			4 25 25
			GP	1 20 10	2 20 10	69 20 10	
				108 30 20			4 22 12
			IM	3 30 20	4 20 10	5 30 30	
				6 30 20	7 20 10	70 40 10	
				71 20 10	104 30 20	105 30 30	
				106 20 10			10 27 17
	H. montaneuse	Montana barley		3 30 20	4 20 10	104 30 20	3 27 17
	H. murinum	Mouse barley	SW	109 30 20			1 30 20
			IM	3 20 20	104 20 30		2 20 20
HOPU	H. pusillum	Little barley		108 10 10			1 10 10
HOVU	H. vulgare	Cultivated barley		109 70 70			1 70 70
KOCR	KOELERIA cristata	PRAIRIE JUNEGRASS	SW	101 70 70	102 65 40	103 35 30	
				109 70 50			4 60 48
			GP	1 60 50	2 60 50	69 55 55	
				108 50 60			4 56 54
			IM	3 70 50	4 60 40	5 60 30	
				6 50 40	7 50 40	16 30 30	
				17 60 50	18 30 30	19 50 50	
				70 70 50	71 30 30	104 70 50	
				105 65 30	106 60 40		
	LAGURUS ovatus	HARESTAIL		109 10 20			1 10 20
LAAU	LAMARCKIA aurea	GOLDENTOP		109 20 20			1 20 20
LECR	LEERSIA oryzoides	RICE CUTGRASS		109 0 0			1 0 0
LEFA	LEPTOCHLOA fascicularis	BEARDED SPRANGLETOP		109 30 20			1 30 20
LEUN2	L. uninervia	Mexican sprangletop		109 0 0			1 0 0
LOLIU	LOLIUM	RYEGRASS		109 70 50			1 70 50
LOMU	L. multiflorum	Italian ryegrass	SW	109 70 50			1 70 50
			IM	6 40 40	7 20 10	70 60 60	3 47 37

PROPER USE FACTORS GRASSES (cont.)

LOPE	L. perenne	Perennial ryegrass	SW	109 70 50			1 70 50
			NW	3 50 30	4 60 40	104 60 30	
				106 60 30			4 60 32
LOTE2	L. temulentum	Darnel ryegrass		109 40 30			1 40 30
MELIC	MELICA	MELIC GRASS	SW	101 70 75	102 65 45	103 50 55	
		(onion grass)		109 70 50			4 64 56
			GP	108 60 60			1 60 60
			NW	3 75 50	4 60 50	5 65 55	
				104 75 50	105 65 55	106 50 30	
				107 60 50			7 64 46
	M. aristata	Bearded melic		109 60 40			1 60 40
	M. bulbosa	Onion grass	SW	101 75 75	102 25 40	103 40 40	
				109 70 50			4 55 51
			NW	3 70 50	4 60 40	70 80 60	
				71 50 20	104 70 50	105 75 40	
				106 60 40	107 60 50		8 66 44
	M. geyeri	Geyer oniongrass		109 60 0			1 60 0
MEIM	M. imperfecta	Coastrange melic		109 60 60			1 60 60
MESP	M. spectabilis	Showy oniongrass	SW	101 75 75	102 60 50	103 50 50	
				109 70 60			4 64 59
			NW	3 60 50	4 60 40	5 60 50	
				71 50 20	104 60 50	105 60 50	
				106 60 40	107 60 50		8 59 44
MESU	M. subulata	Alaska oniongrass		71 10 10			1 10 10
METO	M. torreyana	Torrey melic		109 50 40			1 50 40
MUHLE	MUHLENBERGIA	MUHLY	SW	101 45 55	102 55 40	103 35 40	
				109 60 50			4 49 46
			NW	3 55 35	4 45 40	5 55 40	
				6 50 40	7 30 20	104 55 35	
				105 55 40	106 45 40		8 49 36
	M. andina	Foxtail muhly		70 60 30			1 60 30
MUCU3	M. cuspidata	Plains muhly		1 40 0	2 40 0	69 40 30	
				108 40 20			4 40 12
MUDU	M. dubia	Pine muhly		109 30 10			1 30 10
MURL2	M. filiformis	Pull-up muhly	NW	3 50 40	104 60 40	106 45 40	3 55 40
			SW	109 70 6			1 70 6
MOJO	M. jonesii	Modoc muhly		109 30 30			1 30 30
MUMO	M. montana	Mountain muhly	SW	101 60 60	102 60 40	103 30 35	
				109 60 50			4 52 46
			NW	3 50 40	4 50 40	5 65 35	
				104 50 40	105 65 35	106 50 40	6 55 38
MUPO	M. porteri	Bush muhly		109 60 40			1 60 40
MUPU2	M. pungens	Sandhill muhly		109 10 0			1 10 0
MURA	M. racemosa	Marsh muhly		1 40 20			1 40 20
MURE	M. repens	Red muhly		109 30 20			1 30 20
MURI2	M. rigens	Deergrass		109 30 10			1 30 10
	M. squarrosa	Mat muhly	SW	101 50 55	102 55 40	103 35 40	
				109 50 40			4 50 44
			GP	69 40 30	108 40 20		2 40 25
			NW	3 60 40	4 50 40	5 55 40	
				70 60 30	104 60 40	105 55 40	
				106 50 40			7 56 39
MUTO2	M. torreyi	Ring muhly		109 10 0			1 10 0
	M. virescens	Screwleaf muhly		109 0 0			1 0 0

PROPER USE FACTORS GRASSES (cont.)

MUSQ	MUNROA squarrosa	FALSE BUFFALOGRASS		109	0	0							1	0	0
ORYZO	ORYZOPSIS	RICEGRASS	SW	101	55	79	102	75	50	103	55	75			
				109	70	70							4	64	68
			IW	3	60	40	4	60	50	5	70	70			
				104	60	40	105	75	75	106	55	50	6	63	54
ORAS	O. asperifolia	Roughleaf ricegrass		3	60	40	4	50	30	70	80	60			
				104	60	40							4	62	42
OREX	O. exigua	Little ricegrass		70	60	60							1	60	60
ORHY	O. humenoides	Indian ricegrass	SW	101	60	80	102	80	50	103	55	75			
				109	70	60							4	66	66
			GP	1	50	20	69	55	55	108	50	30	3	52	35
			IW	3	70	50	4	60	50	5	80	75			
				6	50	40	7	40	20	20	40	30			
				21	50	40	23	50	40	24	40	40			
				25	50	50	26	60	0	27	50	50			
				104	70	50	105	60	75	106	60	50			
PANIC	PANICUM	PANICUM(witchgrass)	SW	101	0	40	103	40	0	109	0	0	3	20	20
			GP	108	40	20							1	40	20
PAAG	P. agrostoides	Redtop panicum		109	0	0							1	0	0
PABU	P. bulbosum	Bulb panicum		109	20	20							1	20	20
	P. capillare	Common witchgrass	SW	109	40	20							1	40	20
			IW	104	40	20	107	20	10				2	30	15
	P. occidentale	Cushion witchgrass		3	40	20	4	40	20				2	40	20
	P. obtusum	Vine mesquite		109	20	20							1	20	20
PAVI2	P. virgatum	Switchgrass		1	50	30	2	50	30				2	50	30
	PASALUM distichum	KNOTGRASS		109	20	10							1	20	10
PHAZA2	PHALARIS	CANARY GRASS		109	60	40							1	60	40
PHAR3	P. arundicea	Reed canary grass	GP	69	80	60							1	80	60
			IW	70	80	60	71	70	20				2	75	40
PHLE3	P. lemmoni	Lemmon canary grass		109	40	30							1	40	30
PHMI3	P. minor	Little seed canarygrass		109	30	30							1	30	30
	P. tuberosa	Bulb canarygrass		109	70	60							1	70	60
	P. stenoptera	Harding grass		109	0	0							1	0	0
PHMI3	PHLEUM	TIMOTHY		101	50	80	102	80	60	103	50	35			
				109	70	60							4	70	59
PHAL2	P. alpinum	Alpine timothy	SW	101	80	80	102	0	60	103	50	0			
				109	70	60							4	50	50
			IW	3	80	50	4	80	60	70	80	70			
				71	50	15	104	80	50	106	80	60			
				107	70	60							7	74	52
PHPR3	P. pratense	Timothy	SW	109	80	60							1	80	60
			GP	1	80	70	69	80	70	108	80	60	3	80	67
			IW	3	80	45	4	80	80	5	80	35			
				22	70	25	70	80	70	71	50	25			
				104	80	45	105	80	35	106	80	80			
				107	50	20							10	73	46
PHCO15	PHRAGMITES communis	COMMON REED	SW	109	0	0							1	0	0
			IW	70	0	0							1	0	0
	PLEUROPOGON californicus	ANNUAL SEMAPHOREGRASS		109	50	40							1	50	40
POA++	POA	BLUEGRASS	SW	101	75	75	102	65	50	103	55	55			
				109	70	50							4	56	58
			NW	3	70	60	4	80	50	5	75	55			
				28	55	55	29	27	27	71	60	40			

POA++	POA	BLUEGRASS	NW	104 70 50	105 75 55	105 50 50	
				107 60 30	40 55 55	41 27 27	
				42 55 55	43 27 27	44 50 45	
				45 25 22	46 40 35	47 17 20	
				48 35 35	49 17 20	72 55 55	
				73 27 27	74 55 55	75 27 27	
				76 50 45	77 25 22	78 40 35	
				79 17 20	80 35 35		
POA++	POA (annual)	ANNUAL BLUEGRASS		71 20 10			1 20 10
POAL2	P. alpina	Alpine bluegrass		70 80 70			1 80 70
POAM	P. ampla	Big bluegrass		3 70 60	4 70 60	104 70 60	
				8 30 30	9 60 50	10 60 30	
				11 60 50	24 30 30	25 60 50	
				26 60 30	27 60 50	20 40 30	
				21 70 50	22 60 50	23 70 50	
				6 50 40	7 40 20	71 60 50	
				70 80 70			
POAN	P. annua	Annual bluegrass	SW	109 30 20			1 30 20
			NW	3 35 20	104 35 20	70 80 70	3 50 37
POAR3	P. arida	Plains bluegrass	GP	108 70 70	69 55 55		2 62 62
			NW	70 80 70			1 80 70
POBU	P. bulbosa	Bulbous bluegrass		3 80 60	4 80 60	104 80 60	
				106 80 60	24 40 40	25 50 50	
				26 30 30	27 20 27	6 30 10	
				7 50 20	70 80 70		
POCA	P. canbyi	Canby bluegrass	GP	69 55 55			1 55 55
			NW	3 70 60	4 70 60	104 70 60	
				70 80 70			4 72 62
POCO	P. compressa	Canada bluegrass	SW	109 70 60			1 70 60
			GP	69 55 55	1 70 60	2 70 60	3 65 58
			NW	3 70 60	4 70 60	107 50 40	
				104 70 60	26 70 60	71 70 60	
				70 80 70			7 69 59
POCU3	P. cusickii	Cusick bluegrass	GP	69 55 55			1 55 55
			NW	3 70 60	4 70 60	104 75 55	
				71 50 25			4 66 50
POEP	P. epilis	Skyline bluegrass		71 60 50	70 80 70		2 70 60
POFE	P. fendleriana	Mutton grass	SW	109 70 70			1 70 70
			NW	3 70 60	4 70 60	104 70 60	
				70 80 70			4 72 62
	P. glaucifolia	Bluegrass	GP	69 55 55			1 55 55
			NW	70 80 70			1 80 70
POGR	P. gracillima	Slender bluegrass		70 80 70			1 80 70
POIN	P. interior	Inland bluegrass		70 80 70			1 80 70
POJO	P. juncifolia	Alkali bluegrass		70 80 70			1 80 70
POLE2	P. leptocoma	Bog bluegrass		70 80 70			1 80 70
POLO	P. longiligula	Longtongue muttongrass	SW	109 80 70			1 80 70
			NW	104 70 60	106 70 60	70 80 70	3 73 63
PONE2	P. nervosa	Wheeler's bluegrass		104 70 60	106 80 60	71 20 10	
				70 80 70			4 62 50
PONE3	P. nevadensis	Nevada bluegrass	SW	109 70 50	101 80 80	102 65 50	
				103 50 50			4 66 60
			NW	3 80 60	4 80 60	5 65 50	
				104 80 60	105 65 50	106 80 60	

PROPER USE FACTORS GRASSES (cont.)

PONE3	P. nevadensis	Nevada bluegrass	NW	8 30 30	9 30 50	10 30 30	
				11 60 50	12 30 30	13 60 50	
				14 60 20	15 60 50	16 30 30	
				17 60 50	18 60 20	19 60 50	
				24 30 30	25 60 50	26 60 30	
				27 60 50	20 40 30	21 70 50	
				22 60 50	23 70 50	6 50 40	
				7 50 20	70 80 70	30 65 45	
				32 50 35	34 40 30	36 30 20	
				38 25 15			
POPA2	P. palustris	Fowl bluegrass	SW	109 60 50			1 60 50
			GP	69 40 30			1 40 30
			NW	70 80 70			1 80 70
	P. pattersoni	Patterson bluegrass		70 80 70			1 80 70
POPR	P. pratensis	Kentucky bluegrass	SW	109 80 70	101 80 80	102 80 50	
				103 55 65			4 74 66
			GP	108 60 60	69 55 55	1 70 60	
				2 70 60			4 52 64
			NW	3 80 60	4 80 50	5 80 55	
				107 70 60	104 80 60	105 80 65	
				106 80 50	26 70 60	22 70 60	
				71 70 60	70 80 70		
POPR2	P. pringlei	Pringle bluegrass		70 80 70			1 80 70
PORE	P. reflexa	Nodding bluegrass	NW	70 80 70			1 80 70
			SW	109 80 70	101 60 80	102 80 50	
				103 55 70			4 74 68
	P. rhizomata	Siskiyou bluegrass		70 80 70			1 80 70
PORU	P. rupicola	Timberline bluegrass		70 80 70			1 80 70
POSC	P. scabrella	Pine bluegrass	SW	109 70 50			1 70 50
			NW	3 70 60	4 70 60	104 70 60	
				106 80 50	6 20 10	7 50 20	
				70 80 70			7 63 47
POSE	P. secunda	Sandberg bluegrass	SW	109 60 50	101 45 70	102 45 40	
				103 60 40			4 52 50
			GP	108 60 60	69 55 55	1 40 30	3 52 48
			NW	3 40 60	4 40 60	5 40 40	
				104 40 60	105 45 40	106 40 60	
				8 30 40	9 40 50	10 25 25	
				11 20 20	12 30 40	13 40 50	
				14 25 25	15 20 20	16 30 40	
				17 40 50	18 25 25	19 20 20	
				24 30 40	25 40 50	26 25 25	
				27 20 20	20 25 35	21 45 60	
				22 25 25	23 25 25	6 20 10	
				7 50 20	71 20 25	70 80 70	
	P. stenantha	Trinius bluegrass		70 80 70			1 80 70
POLYP2	POLYPOGON	RABBITS FOOT GRASS		101 0 50	103 50 0		2 25 35
POMO5	P. monspeliensis	Rabbits footpolypogon	SW	109 10 10			1 10 10
			NW	3 20 20	104 20 20	106 10 10	3 17 17
PUAI	PUCCINELLIA	ALKALIGRASS		109 50 40	101 50 55	102 55 30	
				103 25 25			4 45 38
	P. nuttalliana	Nuttal alkaligrass	GP	69 55 55			1 55 55
			NW	3 40 30	104 40 30		2 40 30

PROPER USE FACTORS GRASSES (cont.)

PUSI	P. simplex	Calif. alkaligrass		109 10 10			1 10 10
SCPA	SCHEDONNARDUS paniculatus	TUMBLEGRASS	SW	109 10 20			1 10 20
			GP	108 10 10	69 10 10	1 10 10	3 10 10
			NW	3 10 10	104 10 10		2 10 10
SCPU	SCHIZACHNE purpurascens	FALSEMELIC		69 30 30			1 30 30
SCBR2	SCLEROPOGON brevifolius	BURROGRASS		109 10 20			1 10 20
SECE	SECALE cereale	RYE		109 60 50			1 60 50
SETAR	SETARIA	BRISTLEGRASS		109 10 10	101 0 50	103 40 0	3 17 20
SEGE	S. geniculata	Knot root bristlegrass		109 10 0			1 10 0
SELU2	S. lutescens	Yellow bristlegrass		109 0 0			1 0 0
SEVI4	S. viridis	Green bristlegrass		3 20 10	104 20 10		2 20 10
SITAN	SITANION	SQUIRRELTAIL	SW	109 30 20	101 20 35	102 20 20	
				103 20 30			4 22 26
			NW	3 30 20	4 20 20	5 20 30	
				104 30 20	105 20 30	106 20 20	6 23 23
SIHY	S. hystrix	Bottlebrush squirreltail	SW	109 40 20	101 20 35	102 20 20	
				103 20 30			4 25 26
			GP	108 30 20	1 30 20		2 30 20
			NW	3 50 40	4 20 20	5 20 30	
				104 50 40	105 20 30	106 20 20	
				20 35 25	21 50 30	22 50 20	
				23 40 30	6 40 10	7 30 10	
				71 20 10	70 40 10		
SIJU	S. jubatum	Big squirreltail	SW	109 40 20			1 40 20
			NW	3 40 30	4 20 20	5 20 20	
				104 40 30			4 30 25
SONU2	SORGHASTRUM nutans	INDIAN GRASS		2 40 10			1 40 10
SORGH2	SORGHUM halepense	JOHNSONGRASS		109 50 40			1 50 40
SOVU	S. vulgare	Sorghum		109 70 70			1 70 70
SOSU	S. sudanense	Sudangrass		109 70 70			1 70 70
SPART	SPARTINA	CORDGRASS		101 0 40	103 40 0		2 20 20
SPGR	S. gracilis	Alkali cordgrass	SW	109 40 30			1 40 30
			GP	69 20 10			1 20 10
			NW	3 40 30	104 40 30	106 30 20	3 37 27
SPPE	S. pectinata	Prairie cordgrass	GP	69 10 10	1 10 0	2 10 0	3 10 3
			NW	3 40 30	104 40 30		2 40 30
SPOB	SPHENOPHOLIS obtusata	PRAIRIE WEDGSCALE		69 0 0			1 0 0
SPORO	SPOROBOLUS	DROPSEED	SW	101 45 50	102 50 20	103 25 20	3 40 30
			NW	3 50 25	4 45 20	5 50 20	
				104 50 25	105 50 20	106 45 20	6 48 22
SPAI	S. airoides	Alkali sacaton	SW	109 50 30	101 45 50	102 50 20	
				102 25 20			4 41 30
			GP	108 50 40	1 50 40		2 50 40
			NW	3 50 25	4 45 20	5 50 20	
				104 50 25	105 50 20	106 45 20	
				70 30 10			7 46 20
SPAI	S. asper	Tall dropseed		2 40 10			1 40 10
SPCO4	S. contractus	Spike dropseed		109 50 30			1 50 30
SPCR	S. cryptandrus	Sand dropseed	SW	109 40 20	101 35 35	102 35 10	
				103 15 15			4 31 20
			GP	108 50 40	69 30 20	1 40 20	
				2 40 20			4 40 25
			NW	3 35 15	4 35 10	5 35 15	

PROPER USE FACTORS — GRASSES (cont.)

SPCR	S. cryptandrus	Sand dropseed	IM	104	35	45	105	35	15	106	35	40			
				6	40	20	7	20	10	71	70	40			
				70	70	20							10	41	17
SPGI	S. giganteus	Sacaton		109	40	20							1	40	20
SPHE	S. heterolepis	Prairie dropseed		1	50	40	2	50	40				2	50	40
STIPA	STIPA	NEEDLEGRASS	SW	109	60	50	101	60	55	102	60	40			
				103	40	50							4	55	49
			IM	3	55	40	4	60	40	5	60	50			
				107	60	40	104	55	40	105	60	50			
				106	60	40	20	30	20	21	60	40			
				22	50	10	23	40	20	32	55	30			
				34	45	25	36	35	20	38	30	15			
STCO3	S. columbiana	Subalpine needlegrass	SW	109	60	40	101	55	60	102	50	40			
				103	30	40							4	49	42
			GP	69	50	50							1	50	50
			IM	3	50	40	4	60	40	5	50	40			
				107	50	40	104	50	40	105	50	40			
				106	60	40	26	20	10	71	20	10			
				6	40	30	7	30	30	70	50	40			
STCO4	S. comata	Needle and thread	SW	109	50	40	101	40	40	102	50	40			
				103	40	60							4	45	45
			GP	108	70	40	69	50	50	1	60	40			
				2	60	40							4	60	42
			IM	3	40	30	4	40	40	5	50	60			
				104	40	30	105	50	60	106	40	40			
				6	40	20	7	40	10	24	30	30			
				25	50	40	26	50	0	27	40	30			
				71	20	10	70	60	40	110	65	75			
				112	60	70	114	55	65	116	50	50			
				118	0	25									
STLE2	S. lemmoni	Lemmon needlegrass		71	20	10							1	20	10
STCO5	S. coronata	Crested needlegrass		109	20	20							1	20	20
STLE3	S. lepida	Foothill needlegrass		109	50	40							1	50	40
STLE4	S. lettermanii	Letterman needle-grass	SW	109	70	60	101	70	65	102	65	50			
				103	40	40							4	61	54
			IM	3	60	40	4	70	50	5	65	40			
				104	60	40	105	65	40	106	70	40			
				6	40	30	7	30	30				8	58	40
STOC2	S. occidentalis	Western needlegrass	SW	109	50	40							1	50	40
			IM	24	30	30	25	50	40	26	50	0			
				27	40	30							4	42	25
STPI2	S. pinetorum	Pinewoods needlegrass		3	60	40	104	60	40				2	60	40
STPU2	S. pulchra	California needlegrass		109	60	60							1	60	60
STRI2	S. richardsonii	Richardson needlegrass		69	40	40							1	40	40
STRO3	S. robusta	Sleepygrass		109	30	20							1	30	20
STTH2	S. thurberiana	Thurber needlegrass		6	40	40	7	40	40				2	40	40
	S. spartea var. curtiseta	Shortawn porcupinegrass		69	55	50	1	40	20	2	40	20	3	45	30
STSP3	S. speciosa	Desert needlegrass		109	20	20							1	20	20
STVI4	S. viridula	Green needlegrass		108	70	40	69	55	50	1	60	40			
				2	60	40							4	61	42
STWI	S. williamsi	Williams needlegrass		71	20	10							1	20	10
	TRICDIA	TRICDIA		109	30	30	101	25	40	102	40	15			
				103	40	40							4	34	31

PROPER USE FACTORS GRASSES (cont.)

	T. pulchella	Fluffgrass		109 30 20			1 30 20
	T. mutica	Slim tridia		109 30 20			1 30 20
TRISE	TRISETUM	TRISETUMS		108 50 40			1 50 40
TRCA7	T. canescens	Tall trisetum		71 15 15	70 60 40		2 38 28
TRCE2	T. cernuum	Nodding trisetum		109 50 40			1 50 40
TRSP2	T. spicatum	Spike trisetum	SW	109 60 30	101 65 65	102 65 40	
				103 35 35			4 56 42
			IM	3 60 30	4 60 40	5 65 35	
				107 50 30	6 40 30	7 30 20	
				104 60 30	105 65 35	106 60 40	
				71 50 15			10 54 30
TRWO3	T. wolfi	Wolfs trisetum		71 40 35			1 40 35
TRITI	TRITICUM aestivum	WHEAT		109 70 70			1 70 70

GRASSLIKE PLANTS
PROPER USE FACTORS

CAREX	CAREX (wetmeadows)	SEDGES	SW	109 70 70	101 75 75	102 65 50	
				103 60 45			4 68 60
			GP	2 50 10			1 50 10
			MW	3 70 50	4 70 50	5 65 45	
				107 70 40	104 70 50	105 65 45	
				106 70 50	6 50 50	7 50 50	
				71 50 20			10 63 41
CAREX	CAREX (dry uplands)	SEDGES	SW	109 50 40	101 60 60	102 40 45	
				103 45 35			4 49 45
			GP	1 70 60	2 70 60		2 70 60
			MW	3 50 40	4 40 40	5 30 0	
				107 60 40	104 50 40	103 30 0	
				106 40 40	6 50 40	7 40 20	
				71 40 40			10 43 30
CAAQ	C. aquatilis	Water sedge	GP	69 55 55			1 55 55
			MW	71 40 25			1 40 25
CAAT2	C. atherodes			69 55 55			1 55 55
CAAT5	C. atrata	Marsh sedge		70 50 0			1 50 0
CABE2	C. bebbii			69 50 50			1 50 50
CACO11	C. concinnoides			71 5 0			1 5 0
CADO2	C. douglasii	Douglas sedge	GP	108 60 30			1 60 30
			MW	3 40 20	4 40 20	104 40 20	
				70 80 30			4 50 22
CAEL2	C. eleocharis	Needleleaf sedge		69 0 0			1 0 0
CAEX5	C. exsiccata			3 40 20	4 40 20	104 40 20	3 40 20
CAFE2	C. festivella	Ovalhead sedge		22 40 40	71 40 30		2 40 35
CAFI	C. filifolia	Threadleaf sedge	GP	108 80 80	69 55 55	1 80 70	
				2 80 70			4 74 69
			MW	3 50 40	4 50 40	104 50 40	
				22 50 40	71 50 40	70 80 30	6 55 38
CAGE2	C. geyeri	Elk sedge	GP	108 70 50			1 70 50
			MW	3 50 40	4 50 40	107 50 30	
				104 50 40	106 40 40	14 40 40	
				26 50 50	22 40 40	6 50 40	
				7 30 30	71 30 40	70 30 30	
CAHO5	C. hoodi	Hood's sedge		71 40 30			1 40 30
CAKE2	C. kelloggii	Kellog sedge		3 40 20	4 40 20	104 40 20	3 40 20
CAAL	C. lanuginosa	Wooly sedge		69 40 40			1 40 40
CAAZ	C. latifolia			3 40 20	4 40 20	104 40 20	3 40 20
CANE2	C. nebraskensis	Nebraska sedge		3 40 20	4 40 20	107 70 40	
				104 40 20	26 60 60	22 60 60	
				71 60 60			7 53 40
CAOB4	C. obtusata			69 50 50			1 50 50
CARO6	C. rostrata	Beaked sedge		3 40 20	4 40 20	104 40 20	3 40 20
CASP7	C. sprengelii			69 55 55			1 55 55
	C. stenophylla	Dryland sedge		108 70 60			1 70 60
	C. utriculata			3 40 20	4 40 20	104 40 20	3 40 20
	C. variabilis			3 40 20	4 40 20	104 40 20	3 40 20
CAVI3	C. vicaria			3 40 20	4 40 20	104 40 20	3 40 20
CYPER	CYPERUS	GALINGALE		109 60 40			1 60 40
	C. esculeatus	Rushnut		109 60 40			1 60 40
	C. fendleriana	Rushnut		109 60 40			1 60 40
ELEOC	ELEOCHARIS	SPIKE RUSH	SW	101 20 20	102 0 10	103 10 0	3 10 10
			MW	3 20 10	4 20 10	104 20 10	

PROPER USE FACTORS GRASSLIKE PLANTS (cont.)

ELOC	Eleocharis	Spike rush	NW	106	20	10							1	20	10
ELBO	E. bolanderi	Spike rush		109	60	40							1	60	40
ELPA3	E. palustris	Wiregrass	SW	109	50	40							1	50	30
			GP	69	55	55							1	55	55
			NW	3	20	0	104	20	0				2	20	0
EQUIS	EQUISETUM	HORSETAIL		109	P	P							1	P	P
EQAR	E. arvense	Horsetail		3	0	0	4	0	0	5	0	0			
				104	0	0	105	0	0	106	0	0	6	0	0
EQFL	E. fluvitile	Water horsetail		3	0	0	4	0	0	5	0	0			
				104	0	0	105	0	0	106	0	0	6	0	0
	E. praealtum	Stout scouringbrush		3	0	0	4	0	0	5	0	0			
				104	0	0	105	0	0	106	0	0	6	0	0
ERIOP	ERIOPHORUM	COTTON GRASS		70	0	0							1	0	0
JUNCU	JUNCUS (wet meadow)	RUSH	SW	109	60	60	101	45	45	102	40	0	3	48	35
			GP	108	10	0							1	10	0
			NW	3	40	20	4	40	20	104	40	20			
				106	50	30	71	30	20	70	10	0	6	35	18
JUNCU	JUNCUS (dry uplands)	RUSH	SW	109	40	30							1	40	30
			NW	3	40	20	4	50	30	104	40	20			
				106	50	30	71	10	10				5	38	22
JUBA	J. balticus	Baltic rush	SW	101	45	45	102	40	0				2	42	22
			GP	69	30	30							1	30	30
			NW	3	40	20	4	50	30	5	40	20			
				104	40	20	105	40	20	106	50	30	6	43	23
JUEN	J. ensifolius			3	40	20	4	40	20	104	40	20	3	40	20
JUTO	J. torreyi	Torrey rush		3	40	20	4	40	20	104	40	20	3	40	20
	JUNCOIDES		SW	109	60	60							1	60	60
			NW	107	50	30							1	50	30
	J. parviflorum	Woodrush		101	50	50	102	10	20	103	25	30	3	28	33
LUZUL	LUZULA (dryland)	WOODRUSH		71	40	20							1	40	20
LUZUL	LUZULA (dryland)	WOODRUSH	SW	109	40	20							1	40	20
			GP	108	60	20							1	60	20
			NW	107	40	20							1	40	20
LUCA2	L. campestris	Fieldwood-rush		3	40	20	4	40	20	107	50	30			
				104	40	20	106	50	30				5	[illegible]	24
LUPA4	L. parviflora	Millet woodrush		3	40	20	4	50	20	5	10	30			
				104	40	20	105	10	30	106	50	20	6	33	23
LUSP4	L. spicata	Spike woodrush		3	40	20	4	40	20	107	50	30			
				104	40	20							[illegible]	42	22
SCIRP	SCIRPUS	BULRUSH		70	0	0							1	0	0
SCAM2	S. americanus	Three square American bulrush		69	40	40							1	40	40
SCMI2	S. microcarpus	Panicled bulrush		109	30	30							1	30	30
SCVA	S. validus	Great bulrush		3	10	0	104	10	0				2	10	0
TRMA4	TRIGLOCHIN maritime	COMMON ARROWGRASS		109	P	P							1	P	P
TYPHA	TYPHA	CATTAIL		109	0	0							1	0	0
TYLA	T. latifolia	Cattail		101	0	0	102	0	0	103	0	0	3	0	0
TYAN	T. angustifolia	Narrowleaf cattail		3	0	0	4	0	0	5	0	0			
				104	0	0	105	0	0	106	0	0	6	0	0
TYLA	T. latifolia	Common cattail		3	0	0	4	0	0	5	0	0			
				104	0	0	105	0	0	106	0	0	6	0	0
XETE	XEROPHYLLUM tenax	BEARGRASS		101	0	0	102	0	0	103	0	0	3	0	0

FORBS

PROPER USE FACTORS

ABRON	ABRONIA	SAND VERBENA		109 10 30			1 10 30
ABNA	A. nana			109 10 10			1 10 10
	ACAENA pinnatifida	ACAENA		109 40 50			1 10 50
ACMIL	ACHILLEA lanulosa	COMMON YARROW	SW	109 30 50	101 30 30	102 30 35	
				103 40 60			4 32 44
			GP	108 20 40	59 10 20		2 15 30
			IM	3 30 40	4 30 35	5 30 60	
				107 10 20	6 20 10	7 30 20	
				71 5 30	70 20 40	28 25 45	
				39 12 22	40 25 45	41 12 22	
				42 25 45	43 12 22	44 22 37	
				45 12 17	46 17 32	47 12 17	
				48 17 25	49 12 17	50 25 45	
				51 12 22	52 25 45	53 12 22	
				54 22 37	55 12 17	56 17 32	
				57 12 17	58 17 25	59 25 45	
				60 12 22	61 25 45	62 12 22	
				63 22 37	64 12 17	65 17 32	
				66 12 17	67 12 25	68 12 17	
				72 25 45	73 12 22	74 25 45	
				75 12 22	76 22 37	77 12 17	
				78 17 32	79 12 17	80 17 25	
				81 25 45	82 12 22	83 25 45	
				84 12 22	85 22 37	86 12 17	
				87 17 32	88 12 17	89 17 25	
				90 12 17	91 25 45	92 12 22	
				93 25 45	94 12 22	95 22 37	
				96 12 17	97 17 32	98 12 17	
				99 17 25	100 12 17		
	ACHYRACHAENA mollis	BLOW-WIVES		109 10 10			1 10 10
ACONI	ACONITUM	MONKSHOOD	SW	101 5 5	102 0 35	103 35 0	3 13 13
			IM	3 0 35	4 10 35	107 10 50	3 7 10
ACCO4	A. columbianum	Western monkshood	SW	109 30 20	101 5 5	102 0 35	
				103 35 0			4 13 15
			IM	3 0 35	4 10 35	71 30 40	3 13 37
	ACTAEA spicata var. arguta	Black BANEBERRY	SW	109 0 0	101 0 0	102 0 25	
				103 25 25			4 6 12
			IM	3 0 25	4 0 25	5 0 25	3 0 15
ADBI	ADENOCAULON bicolor	ADENOCAULON	SW	109 10 10			1 10 10
			IM	107 10 40	71 20 60		2 15 50
	ADENOSTEGIA ramosa	PLUMEWEED	SW	103 5 5			1 5 5
			IM	3 0 10	5 0 10		2 0 10
AGAST	AGASTACHE	HYSSOP		70 20 40			1 20 40
AGUR	A. urticifolia	Agastache	SW	109 30 40	101 50 45	102 0 70	
				103 70 0			4 38 39
			IM	3 45 70	4 20 50	107 20 50	
				6 30 20	7 50 50	71 20 50	
				28 50 70	29 25 35	40 50 70	
				41 35 35	42 50 70	43 25 35	
				44 40 60	45 20 30	46 35 50	
				47 20 25	48 30 40	49 20 25	
				50 50 70	51 25 35	52 50 70	
				53 25 35	54 40 60	55 20 30	
				56 35 50	57 20 25	58 30 40	

PROPER USE FACTORS — FORBS (cont.)

Code	Scientific name	Common name	Region				
AGUR	A. urticifolia	Agastache	NW	59 50 70	60 25 35	61 50 70	
				62 25 35	63 40 60	64 20 30	
				65 35 50	66 20 25	67 30 40	
				68 20 25	72 50 70	73 25 35	
				74 50 70	75 25 35	76 40 60	
				77 20 30	78 35 50	79 20 25	
				80 30 40	81 50 70	82 25 35	
				83 50 70	84 25 35	85 40 60	
				86 20 30	87 35 50	88 20 25	
				89 30 40	90 20 25	91 50 70	
				92 25 35	93 50 70	94 25 35	
				95 40 60	96 20 30	97 35 50	
				98 20 25	99 30 40	100 25 25	
AGOSE	AGOSERIS	MOUNTAIN DANDELION	SW	109 40 20	101 30 60	102 20 55	
				103 60 35			4 38 55
			GP	108 50 60			1 50 60
			NW	3 35 65	4 30 50	5 10 30	
				107 30 60	6 30 30	7 50 50	
				71 30 50	70 60 80		8 34 52
AGGL	A. glauca	Smooth mountain	SW	109 50 70			1 50 70
		dandelion	NW	3 60 80	4 60 80	107 60 70	3 60 77
AGGR	A. grandiflora	Mountain dandelion		3 60 80	5 60 80		2 60 80
AGHE2	A. heterophylla	Annual agoseris		3 60 80			1 60 80
	A. taraxacifolia	False mountain	SW	109 30 30	101 35 35	102 10 65	
		dandelion		103 65 30			4 35 40
			NW	3 35 65	4 35 65	5 10 30	
				107 30 60			4 23 55
ALLIU	ALLIUM	WILD ONION	SW	109 10 30	101 15 20	102 10 40	
				103 50 35			4 21 31
			GP	108 20 40			1 20 40
			NW	3 50 75	4 25 40	107 50 70	
				6 35 0	7 50 0	71 0 20	
				70 20 50			7 33 36
ALAC4	A. acuminatum	Tapertip onion	SW	109 10 20	101 15 25	102 0 40	
				103 50 10			4 19 21
			NW	3 50 75	4 25 40	107 50 70	3 42 62
ALCE2	A. cernum	Nodding onion		3 60 60			1 60 60
	A. cusickii			3 60 60			1 60 60
	A. incisum			3 60 60			1 60 60
ALMA5	A. macrum			3 60 60			1 60 60
ALVA	A. validum	Pacific onion		71 30 50			1 30 50
	ALSINE	CHICKWEED		101 5 10	102 0 25	103 25 20	3 10 18
	A. jamesiana	Tuber starwort		109 20 20	101 20 15	102 0 30	
				103 60 0			4 25 21
AMSIN	AMSINCKIA	FIDDLENECK		109 10 10			1 10 10
AMDO	A. douglasiana	Douglas fiddleneck		109 20 40			1 20 40
AMIN3	A. intermedia	Fireweed fiddleneck		109 20 40			1 20 40
ANAR	ANAGALLIS arvensis	SCARLET PIMPERNAL		109 10 10			1 10 10
ANAPH	ANAPHALIS	EVERLASTING		70 0 10			1 0 10
	ANDROSACE diffusa	ROCK JASMINE	SW	109 10 10	101 0 10	102 0 5	
				103 15 0			4 6 6
			NW	3 0 10	4 0 5		2 0 8
ANEMO	ANEMONE	WINDFLOWER		107 0 10	70 0 10		2 0 10
	A. ludoviciana	Pasqueflower		108 0 40			1 0 40

PROPER USE FACTORS FORBS (cont.)

ANOR	A. oregana	Oregon anemone		71	0	20							1	0	20
ANPI	A. piperi	Wind flower		3	0	10							1	0	10
ANGEL	ANGELICA	ANGELICA	SW	109	40	60							1	40	60
			IM	70	0	80							1	0	80
ANBR5	A. breweri	Brewer angelica		109	30	50							1	30	50
	A. lyallii	Lyall angelica		3	60	80	107	60	70	71	50	70	3	57	73
ANWH	A. wheeleri	Wheeler angelica	SW	109	40	60	101	40	40	102	0	45			
				103	50	0							4	32	36
			IM	3	40	50	4	20	50	107	30	50	3	30	50
	ANNUALS	Unidentified annuals	SW	101	20	20	102	20	20	103	20	20	3	20	20
			IM	107	10	20	6	10	10	7	20	20	3	13	17
	ANOGRA	WHITE EVENING PRIMROSE		70	0	60							1	0	60
	A. albicaulis	White evening primrose		108	10	20							1	10	20
	A. pallida	Pale evening primrose		109	0	0	103	5	0				2	2	0
ATEN	ANTENNARIA	PUSSY TOES		109	0	10							1	0	10
ANAR5	A. argentea			109	0	20							1	0	20
APOLY4	APOCYNUM	INDIAN HEMP	SW	109	10	30	101	0	5				2	5	18
			IM	107	0	20							1	0	20
AQUIL	AQUILEGIA	COLUMBINE	SW	109	30	30	101	25	30	102	0	80			
				103	70	0							4	31	35
			IM	3	20	30	4	25	80	107	20	30			
				70	20	30							4	21	42
AQCO	A. coerulea	Colorado columbine		3	20	30	107	20	30				2	20	30
AQFL	A. flavascens	Yellow columbine		3	20	30	107	20	30	71	20	40	3	20	33
AQFO	A. formosa	Sitka columbine	SW	109	30	30	101	25	30	102	0	70			
				103	80	0							4	34	32
			IM	3	20	30	4	25	80	107	20	30			
				71	20	40							4	21	45
AQFO	A. truncata (now formosa)	Sitka columbine		109	30	60							1	30	60
ARAB12	ARABIS	ROCKCRESS	SW	109	30	40	101	5	10	102	10	10			
				103	15	10							4	15	18
			GP	108	10	30							1	10	30
			IM	107	10	40	71	10	30	70	10	40	3	10	37
	A. arvense	Rockcress		3	10	30							1	10	30
ARLY	A. lyalli	Lyall rockcress		3	10	30							1	10	30
ARSP	A. sparsiflora			3	10	30	4	10	15				2	10	23
ARENA	ARENARIA	SANDWART	SW	109	10	20	101	5	0	102	0	10			
				103	15	0							4	8	8
			GP	108	0	10							1	0	10
			SW	70	20	50							1	20	50
ARCA7	A. capillaris (now formosa)	Fescue sandwart		109	0	20							1	0	20
	A. foliosa			109	0	30							1	0	30
	ARGENTINA	SILVER WEED		70	10	30							1	10	30
ARNIC	ARNICA	ARNICA	SW	109	20	30	101	20	0	102	0	25			
				103	15	0							4	14	14
			IM	3	0	15	4	10	15	107	0	30			
				71	0	10	70	10	30				5	4	20
ARCO9	A. cordifolia	Heartleaf arnica	SW	109	10	20	101	10	0	102	0	30			
				103	25	0							4	11	12
			IM	3	0	15	4	10	30	107	0	30			
				71	0	10							4	2	21
ARDI7	A. foliosa	Leafy arnica	SW	109	20	40							1	20	40

PROPER USE FACTORS FORBS (cont.)

ARDI7	A. foliosa	Leafy arnica	MW	71 15 35			1 15 35
ARFU3	A. fulgens	Orange arnica		71 10 20			1 10 20
ARLA8	A. latifolia	Broadleaf arnica		107 10 40	71 0 10		2 5 25
	A. pedunculata	Corm arnica		3 0 10			1 0 10
ARLU	ARTEMISIA ludoviciana	CUDWEED SAGE BRUSH	SW	109 20 30			1 20 30
			GP	108 10 10			1 10 10
ARVU	A. vulgaris	Mugwart		109 10 20			1 10 20
ASCLE	ASCLEPIAS	MILKWEED	SW	109 P P	101 5 5	102 0 5	
				103 5 0			4 2 2
			MW	3 P P			1 P P
ASER	A. eriocarpa	Woolypod milkweed		109 P P			1 P P
	A. galiodes	Poison milkweed		109 P P			1 P P
ASSP	A. speciosa	Showy milkweed		109 20 40			1 20 40
ASTER	ASTER	ASTER	SW	109 10 20	101 20 25	102 12 40	
				103 35 15			1 19 25
			GP	108 10 20			1 10 20
			MW	3 5 10	4 20 40	5 0 0	
				107 10 20	6 10 10	7 10 20	
				71 10 20	70 20 40	28 25 30	
				29 15 20			10 12 21
ASTER	ASTER (now include Machaeran thera)			40 25 30	41 15 20	42 25 30	
				43 15 20	44 20 25	45 15 15	
				46 25 20	47 10 10	48 10 15	
				49 10 10			10 16 20
MAMU	A. adsecndens	Aster		70 20 40			1 20 40
	A. adsurgens			69 20 40			1 20 40
	A. apricus	Aster		70 20 40			1 20 40
	A. brevibracteatus	Aster		70 20 40			1 20 40
	A. burkei	Aster		70 20 40			1 20 40
ASCA6	A. campestris	Aster		70 20 40			1 20 40
	A. ciliomarginatus			70 20 40			1 20 40
ASAF2	A. commutatus	Aster		70 20 40			1 20 40
ASCO3	A. conspicuus	Showy aster	GP	69 60 60			1 60 60
			MW	3 10 20	107 10 30	70 10 60	3 10 37
	A. cusickii	Aster		70 20 40			1 20 40
ASEA	A. eatonii	Aster		70 20 40			1 20 40
	A. elegans	Low Italian aster		3 5 10			1 5 10
ASEN2	A. engelmanni	Engelmann aster	SW	101 35 35	102 0 55	103 55 0	3 30 30
			MW	3 20 40	4 20 50	107 20 40	
				70 20 40			4 20 42
ASER3	A. ericoides	Health aster		69 20 40			1 20 40
	A. fremontii	Fremont aster		3 10 20	70 20 40		2 15 30
	A. geyeri	Aster		70 20 40			1 20 40
ASHE	A. hesperius	Aster		70 20 40			1 20 40
ASIN3	A. integrifolius	Thickstem aster		70 20 40			1 20 40
ASJE	A. jessicae	Aster		70 20 40			1 20 40
	A. kumleinii	Aster		70 20 40			1 20 40
ASLA5	A. laevis	Smooth aster	GP	69 20 40			1 20 40
			MW	3 10 20	70 20 40		2 15 30
ASLI2	A. longifolius	Longleaf aster		3 10 20			1 10 20
	A. meritus	Aster		70 20 40			1 20 40
	A. multiflorus	Wreath aster		70 20 40			1 20 40
	A. nelsonii	Aster		70 20 40			1 20 40
ASOC	A. occidentalis	Aster		70 20 40			1 30 40

PROPER USE FACTORS FORBS (cont.)

	A. oreganus	Aster		70 20 10			1 20 10
	A. pulverulenta			3 5 10			1 5 10
	A. scopulorum	Crag Aster	SW	102 0 5	103 10 0		2 5 2
			GP	3 0 10	4 0 5		2 0 8
	A. stenomeres	Northwest aster		3 5 10			1 5 10
ASTRA	ASTRAGALUS	RATTLE WEED LOCO	SW	109 20 30	101 15 10	102 0 10	
				103 15 0			4 12 12
			NW	4 0 10	107 10 20	70 40 50	3 17 27
ASTRA	ASTRAGALUS (wooly)						
ASAB	A. aboriginorum	Loco		70 40 50			1 40 50
ASAD3	A. adsurgens	Prairie milkvetch		69 10 20			1 10 20
ASAG2	A. agrestis	Loco		70 40 50			1 40 50
ASAL7	A. alpinus	Loco		70 40 50			1 40 50
ASAM3	A. americanus	Loco		70 40 50			1 40 50
ASTRA	ASTRAGALUS (bicolor)						
	A. campestris	Timber poison vetch		70 40 50			1 40 50
	A. caryocarpus	Loco		70 40 50			1 40 50
ASCI2	A. cibarius	Loco		70 40 50			1 40 50
ASCO12	A. convallarius	Timber poison vetch		109 P P			1 P P
ASCR2	A. crassicarpus	Loco		70 40 50			1 40 50
ASMI0	A. decum bens	Loco		70 40 50			1 40 50
ASDR3	A. drummondii	Drummond milkvetch		70 40 50			1 40 50
	A. flexuesus	Loco		70 40 50			1 40 50
	A. glabriusculus	Loco		70 40 50			1 40 50
ASGL4	A. goniatus	Nickleaf milkvetch		70 40 50			1 40 50
	A. hylophilus	Loco		70 40 50			1 40 50
	A. hypoglottis			69 10 20			1 10 20
ASFI	A. macounii	Loco		70 40 50			1 40 50
	A. microcystis	Loco		70 40 50			1 40 50
	A. missouriensis	Loco		70 40 50			1 40 50
ASMO7	A. mollissimus	Poison vetch		108 0 10			1 0 10
ASMI10	A. mortonii	Morton loco		70 40 50			1 40 50
	A. pauciflorus	Loco		70 40 50			1 40 50
ASFI	A. stenophyllus			6 40 0	7 30 0		2 35 0
ASCR2	A. succulentus	Loco		70 40 50			1 40 50
ATRIP	ATRIPLEX	SALTBUSH		109 0 10			1 0 10
ATNU2	A. nuttallii	Nuttall saltbush		69 20 30			1 20 30
ATRO	A. rosea	Saltbush		108 10 20			1 10 20
BAERI	BAERIA	GOLD FIELDS		109 10 20			1 10 20
BADE	B. debilis	Gold fields		109 10 20			1 10 20
BAILE	BAILEYA	BAILEYA	SW	109 10 10	101 0 20	102 0 5	
				103 20 0			4 5 9
			NW	3 20 20	4 0 5		2 10 12
BALSA	BALSAMORHIZA	BALSAM ROOT	SW	109 30 50	101 25 35	102 20 50	
				103 50 35			4 31 42
			GP	108 40 60			1 40 60
			NW	3 20 30	4 20 30	5 30 40	
				107 20 10	70 10 30	44 5 10	
				45 5 10	46 5 10	47 0 5	
				48 5 10	49 0 5	72 5 10	
				73 5 10	74 5 10	75 5 10	
				76 5 10	77 5 10	78 5 10	
				79 0 5	80 5 10	80 0 5	
BAHI	B. hirsuta	Hairy balsamroot		3 10 20			1 10 20

PROPER USE FACTORS — FORBS (cont.)

	B. hispidula			109 10 20			1 10 20
BAHO	B. hookeri	Hooker balsamroot	SW	101 25 30	102 30 50	103 50 50	3 35 43
			NW	3 40 50	4 25 50	5 30 50	
				6 30 10	7 40 20		5 35 36
	B. incana	Balsamroot	SW	101 25 30	102 30 50	103 50 50	3 35 43
			NW	70 40 60			1 10 20
	B. incisum			3 20 30			1 20 30
BAMA4	B. macrophylla	Big leaf balsamroot	SW	101 30 35	102 0 55	103 55 0	3 28 30
			NW	3 20 30	4 30 55	70 10 60	3 30 43
	B. sagitta	Arrowleaf	SW	109 40 60	101 25 40	102 30 40	
				103 55 40			1 38 45
			GP	108 30 50			1 30 50
			NW	3 40 60	4 20 50	5 30 40	
				107 20 50	6 30 10	7 10 20	
				71 20 40	70 40 50		1 31 40
	B. terebinthacea	Turpentine balsam-root		71 0 10			1 0 10
BASSI	BASSIA	PAHUTE WEED		109 40 30			1 40 30
BAHY	B. hyssopifolia	Fivehook bassia		3 10 20			1 10 20
BOISD	BOISDUVALLIA	SPIKE PRIMROSE		109 20 30			1 20 30
BODE	B. densiflora	Dense spike primrose		109 30 40			1 30 40
BOGL	B. glabella			109 20 30			1 20 30
BOYKI	BOYKINIA major	SIERRA BOYKINIA		107 0 20			1 0 20
BRASS2	BRASSICA	MUSTARD	SW	109 10 20	101 5 10	102 10 15	
				103 15 15			1 10 15
			GP	108 10 20			1 10 20
			NW	3 20 30	4 5 15	5 10 20	
				107 10 30	6 20 10	7 30 10	
				70 10 30			1 15 21
	B. arvensis	Charlock	SW	109 0 10			1 0 10
			NW	3 20 30			1 20 30
BRCA2	B. campestris	Common yellow mustard	SW	109 10 20			1 10 20
			NW	71 10 30			1 10 21
BRNI	B. nigra	Black mustard		3 20 30			1 20 30
BRODI	BRODIAEA	BRODIEA		109 10 20			1 10 20
BRBU2	B. capitata	Bluedicks brodiea		109 10 20			1 10 20
BRLA2	B. laxa	Grassnut brodiea		109 10 20			1 10 20
	CALANDRINIA caulescens	CALANDRINIA		109 20 20			1 20 20
CALOC	CALOCHORTUS	MARIPOSA LILY	SW	109 10 20	101 10 20	102 0 25	
				103 30 0			1 12 16
			GP	108 0 50			1 0 50
			NW	3 20 30	4 10 25	107 10 20	
				70 0 50			1 10 31
CAEL	C. elegans	Northwestern mariposa		3 20 30			1 20 30
CAEU	C. eurycarpus	Broad fruit mariposa		3 20 30			1 20 30
CAMA5	C. macrocarpus	Mariposa lily		3 20 30			1 20 30
	C. majus			3 20 30			1 20 30
	C. nuttallii	Sego lily		3 20 30	4 30 10		3 25 20
CALTH	CALTHA	MARSH MARIGOLD		70 0 40			1 0 40
CABI2	C. biflora	Twinflower marsh marigold		109 10 10			1 10 10
CALE4	C. leptosepala	Elkslip marsh mari-gold	SW	109 10 10	101 5 5	102 0 15	
				103 20 10			1 9 10
			NW	3 10 10	4 5 15	5 0 10	

				PROPER USE FACTORS			FORBS (cont.)
CALE4	C. leptosepala	Elkslip marsh marigold	IM	107 0 10			1 1 11
CALYP4	CALYPTRIDIUM						
CAUM 2	C. umbellatum	Pussypaws		109 10 20			1 10 20
CAMAS	CAMASSIA	CAMAS		109 10 30			1 10 30
CAQV2	C. quamash	Common camas	SW	109 10 30			1 10 30
			IM	3 0 10	107 0 20		2 0 15
CAQU2	C. quamash	Common camas		71 0 20			1 0 20
CAMPA	CAMPANULA	HAREBELL	GP	108 10 30			1 10 30
			IM	70 10 10			1 10 10
CARO2	C. rotundifolia	Bluebell		3 10 10			1 10 10
	CAPNOIDES	CORYDALIS		70 10 30			1 10 30
	C. montana	Mountain corydalis		109 10 10	101 0 10	103 20 0	3 10 7
	CAPSELLA	SHEPHERD'S PURSE		70 0 30			1 0 30
CABU2	C. bursa-pastoris	Shepherd's purse	SW	109 10 30	102 0 15	103 10 15	3 7 20
			GP	108 10 10			1 10 10
			IM	3 0 10	4 0 15	5 0 15	
				107 0 10	71 0 10		5 0 12
CARDA	CARDAMINE	BITTERCRESS		71 10 20			1 10 20
CAC06	C. cordifolia	Heartleaf bittercress	SW	109 10 10	101 10 10	102 0 15	
				103 15 0			4 9 9
			IM	3 10 15	5 10 15		2 10 15
CAPE3	C. Pennsylvanica	Pennsylvania bittercress		3 10 20			1 10 20
	C. draba	Pepperweed whitetop		3 10 30			1 10 30
	CARUM	CARAWAY		70 30 50			1 30 50
	C. gairdneri	Squaw root	SW	109 30 10			1 30 10
			IM	3 30 30			1 30 80
CAST12	CASTILLEJA	INDIAN PAINTBRUSH	SW	109 10 20	101 10 10	102 0 15	
				103 20 0			4 10 11
			GP	108 10 30			1 10 30
			IM	3 10 20	4 10 20	107 0 20	
				6 10 10	7 20 10	71 0 10	
				70 10 30			7 19 17
CAAN7	C. angustifolia	Indian paintbrush		3 10 20	4 10 20		2 10 20
CAEX6	C. exilis	Painted cup		3 10 20	4 10 20		2 10 20
	C. lutescens	Painted cup		3 10 20	4 10 20		2 10 20
CAMI12	C. miniata	Scarlet painted cup		3 10 20	4 10 20		2 10 20
	C. rhexifolia	Splitleaf painted cup		3 10 20	4 10 20		2 10 20
CARH4	C. latifolia	Seaside painted cup		109 10 20			1 10 20
CAULA	CAULANTHUS	WILD CABBAGE	SW	101 15 15	102 0 25	103 25 25	3 13 22
			IM	3 10 20	4 15 25		2 12 22
CAP14	C. pilosus	Wild cabbage		3 10 20			1 10 20
	CENTAUREA melitensis	NAPA THISTLE		109 0 10			1 0 10
	C. solstitialis	Yellow star thistle		109 0 10			1 0 10
CERAS	CERASTIUM	CERASTIUM		71 5 10	70 10 30		2 8 20
CEAR4	C. arvense	Field chickweed	SW	109 10 10			1 10 10
			GP	108 10 30			1 10 12
			IM	3 10 30			1 10 30
CEV13	C. viscosum	Mouse ear chickweed		109 10 10			1 10 10
CEVU	C. vulgatum	Chickweed		3 0 10			1 0 10
CHAEN	CHAENACTIS	FALSE YARROW	SW	109 0 10			1 0 10
			IM	70 0 30			1 0 30
	CHAMAENERION		SW	101 30 30	102 0 65	103 50 0	3 27 [illegible]

PROPER USE FACTORS — FORBS (cont.)

	Chamaenerion		NW	70	10	70							1	10	70
	C. angustifolium	Fireweed		101	30	30	102	0	65	103	50	0	3	27	32
	CHEIRINIA	BLISTER CRESS		109	10	10	101	10	10	102	0	15			
				103	25	10							4	11	11
CHENO	CHENOPODIUM	GOOSEFOOT	SW	109	20	30	102	0	30	103	45	35	3	22	32
			NW	3	10	30	4	10	20	5	0	35			
				107	10	30	71	10	30	70	20	30	6	10	29
CHAL7	C. album	Lamb's quarter	SW	109	20	30	102	0	30	103	45	35	3	22	32
		goosefoot	GP	108	10	30	69	10	40				2	10	35
			NW	3	10	30	4	20	30	5	20	15	3	17	25
CHBO2	C. botyrs	Jerusalemoak goosefoot		3	10	30	4	10	30				2	10	30
CHGL3	C. glaucum	Oakleaf goosefoot		3	10	30	4	10	30				2	10	30
CHLE4	C. leptophyllum	Slimleaf goosefoot	GP	69	10	40							1	10	10
			NW	3	10	30	4	10	30				2	10	30
CHZOR3	CHLOROGALUM	SOAP PLANT		109	30	10							1	30	10
	C. pomeridianum	Amole soapplant		109	30	10							1	30	10
CHRS7	CHRYSOPSIS	GOLDEN ASTER	SW	109	10	20	101	15	10	102	5	30			
				103	20	55							4	11	29
			GP	108	20	40							1	20	10
			NW	3	10	20	4	15	30	5	5	55			
				70	20	40							4	12	36
CHGR4	C. hispida	Rough goldenaster		69	10	10							1	10	10
CHVI6	C. villosa	Hairy fold aster		108	0	10	69	10	10				2	5	10
CICUT	CICUTA	WATER HEMLOCK		109	P	P							1	P	P
	C. californica	California water hemlock		109	P	P							1	P	P
	C. vagans	Tuber water hemlock		3	P	P	4	P	P	5	P	P			
				107	P	P							4	P	P
CIRSI	CIRSIUM	THISTLE	SW	109	20	30	101	25	25	102	25	10			
				103	15	10							4	21	19
			GP	108	30	20							1	30	20
			NW	3	10	10	4	10	10	107	10	20			
				71	5	20	70	30	20				5	13	15
CIAR4	C. arvense	Canada thistle		3	10	10	4	10	10				2	10	10
CIED	C. edule	Indian thistle		3	10	10	4	10	10				2	10	10
CIIO	C. lanceolatum	Bull thistle	SW	109	20	30							1	20	30
			NW	3	10	10	4	10	10				2	10	10
	C. palousense			3	10	10	4	10	10				2	10	10
CIUN	C. undulatum	Wavyleaf thistle		3	10	10	4	10	10				2	10	10
CLARK	CLARKIA	CLARKIA		109	10	20							1	10	20
CLPU	C. pulchella	Elkhorn clarkia		3	10	20	4	10	20	71	0	10	3	7	17
	C. rhomboidea			3	10	20	4	10	20				2	10	20
CLAYT	CLAYTONIA	SPRING BEAUTY		71	0	10							1	0	10
CLLA2	C. lanceolata	Lanceleaf spring	SW	102	0	10	103	20	0				2	10	5
		beauty	NW	3	0	20	5	0	20	107	0	20	3	0	20
	C. perfoliata	Miners lettuce	SW	109	10	20							1	10	20
			NW	107	10	30							1	10	30
CLEMA	CLEMATIS	VIRGIN'S BOWER		109	10	10							1	10	10
CLHI	C. hirsatissima	Oldmans whiskers		3	0	10	71	0	10				2	0	10
CLEOM	CLEOME	SPIDER PLANT		109	10	10	101	10	10	102	10	10			
				103	10	10							4	10	10
CLLU2	C. lutea	Bee-flower	SW	109	10	10	101	10	10	102	10	10			
				103	10	10							4	10	10

PROPER USE FACTORS FORBS (cont.)

CLLU2	C. lutea	Bee-flower	IM	3 10 10	4 10 10	5 10 10	3 10 10
CLSE	C. serrulata	Rocky Mt. bee plant	SW	109 10 10	101 10 10	102 10 10	
				103 10 10			4 10 10
			SW	3 10 10	4 10 10	5 10 10	3 10 10
CLUN2	CLINTONIA uniflora	QUEENCUP BEADLILY		107 10 60			1 10 60
	COGSWELLIA	BAISCUIT ROOT	SW	109 10 30	101 5 15	103 15 10	
				103 25 25			4 14 20
			GP	108 20 50			1 20 50
			IM	70 30 50			1 30 50
	C. platyphalla	Barestem lomation		109 10 20	101 10 15	102 0 10	
				103 25 0			4 11 11
COLLI	COLLINSIA	BLUE-EYED MARY		109 10 20	102 0 20	103 20 0	3 10 13
	C. bicolor	Chinese houses		109 20 20			1 20 20
	C. tenella	Slender collinsia		102 0 20	103 20 0		2 10 10
	COLLOMIA	GILIA		109 10 20	103 30 0		2 20 10
	C. linearis	Slender leaved gilia	SW	109 20 30	103 30 0		2 25 15
			IM	3 0 10			1 0 10
COMAN	COMANDRA	TOAD FLAX		70 10 20			1 10 20
COPA5	C. pallida	Bastard toadflax	SW	109 0 10	103 10 15		2 5 12
			IM	3 10 20	5 0 15		2 5 18
COUM	C. umbellata	Common comandra		109 10 20			1 10 20
CONIV	CONIUM maculatum	PAISON HEMLOCK		109 P P			1 P P
CONVO	CONVOLVULUS	MORNING GLORY		109 20 30			1 20 30
COAR4	C. arvensis	Archard morning glory		109 20 30			1 20 30
COOC	COPTIS occidentalis	WESTERN GOLDEN THREAD		107 0 20			1 0 20
CORDY	CORDYLANTHUS	BIRD'S BEAK		109 10 10			1 10 10
	C. montana	Mountain corydalis	SW	109 10 10			1 10 10
			IM	3 10 20	4 0 30		2 5 25
	C. ramosa	Plume weed		3 0 10	5 0 10		2 0 10
COCAI3	CORNUS canadensis	BUNCHBERRY DOGWOOD		107 10 50			1 10 50
CORYD	CORYDALIS	CORYDALIS		107 10 30			1 10 30
CREPI	CREPIS	HAWKSBEARD	SW	109 40 40	101 25 25	102 50 40	
				103 50 30			4 31 34
			GP	108 30 80			1 30 80
			IM	3 15 40	4 15 35	5 30 60	
				107 60 70	6 20 10	7 20 20	
				71 40 50	70 30 80		8 29 39
CRAC2	C. acuminata	Taper tip hawksbeard	SW	109 30 60	101 35 40	102 0 55	
				103 60 0			4 31 39
			IM	3 30 70	4 20 50	107 60 70	
				71 20 50			4 32 60
CRBA3	C. barbigera	Hawksbeard		3 30 70			1 30 70
	C. gracilis	Hawksbeard		3 30 70			1 30 70
	C. accidentalis	Hawksbeard		3 30 70			1 30 70
	C. scopulorum	Yellowstone hawks-beard	SW	101 15 15	102 30 35	103 40 60	3 25 37
			IM	3 15 40	4 15 35	5 30 60	3 20 45
CRYPT	CRYPTANTHA	NIEVITAS		101 10 20	102 0 10	103 20 0	3 10 10
CRNA2	C. nana			109 10 20	101 10 20	102 0 10	
				103 20 0			4 10 12
CUSCU	CUSCUTA	DODDER		109 20 20			1 20 20
CUCA	C. californica	California dodder		109 40 50			1 40 50
CYNOG	CYNOGLOSSUM	HOUND'S TONGUE		109 10 10			1 10 10
DAPU3	DAUCUS pusillus	RATTLESNAKE WEED		109 10 10			1 10 10
DAME2	DATURA metaloides	JIMPSON WEED		109 10 10			1 10 10

PROPER USE FACTORS — FORBS (cont.)

DELPH	DELPHINIUM	LARKSPUR	SW	109	14	40	101	5	20	102	0	30			
				103	40	0							4	11	22
			NW	3	P	30	4	P	30	107	P	30			
				71	P	20							4	P	28
DEAN	D. andersonii	Anderson larkspur		3	P	30	4	P	30				2	P	30
DEBE2	D. barbeyi	Tall larkspur	SW	109	P	P	101	45	60	102	0	50			
				103	5	50							4	12	40
			NW	3	P	60	4	15	60	107	P	40			
				7	40	40	70	0	60				5	11	52
DEBI	D. bicolor	Low larkspur	GP	108	0	50	69	0	10				2	0	50
			NW	3	P	30	4	P	30	107	P	30			
				7	20	20	70	0	30				5	4	34
	D. brownii	Tall larkspur		70	0	60							1	0	60
DEDE2	D. depauperatum	Slim larkspur		3	P	30	4	P	30				2	P	30
DEME	D. menziesii	Low larkspur	SW	109	P	P	101	5	20	102	0	30			
				103	40	0							1	11	12
			NW	71	P	20							1	P	20
DEMV	D. nelsonii	Spring larkspur		3	P	30	4	P	30				2	P	30
DEOC	D. occidentale	Dunce cup larkspur		71	P	50							1	P	50
	D. reticulatum			3	P	30	4	P	30				2	P	30
DESCU	DESCURAINIA	TANSY MUSTARD	SW	109	10	10							1	10	10
			NW	107	10	10	71	10	20				2	10	15
	D. incisa	Western tansy mustard	SW	109	10	20							1	10	20
			NW	107	10	10							1	10	10
	DICENTRA formosa	BLEEDING HEART		109	10	20							1	10	20
	DICHROPHYLLUM	SNOW-ON-THE-MT.		70	0	30							1	0	30
DISPO	DISPORUM	FAIRYBELLS		70	0	10							1	0	10
DODEL	DODECATHEON	SHOOTING STAR	SW	109	0	10							1	0	10
			GP	108	10	50							1	10	50
			NW	107	0	10	70	10	30				2	5	45
DOHE	D. hendersonii	Mosquito bills		109	10	20							1	10	20
DOEL	DOWNINGIA elegans	DOWNINGIA		109	10	20							1	10	20
DRABA	DRABA	DRABA	SW	109	10	20							1	10	20
			NW	107	0	10	71	0	10	70	10	20	3	3	12
DRVE2	D. verna	Whitlow-grass		3	0	10							1	0	10
	DRYMOCALLIS	CINQUEFOIL	SW	109	20	20	101	15	30	102	0	10			
				103	40	0							4	19	22
			NW	70	10	20							1	10	20
	D. glandulosa	Gland cinquefoil		101	20	20	102	0	50	103	35	0	7	13	23
ECHIN5	ECHINOCYSTIS	BIG ROOT		109	20	30							1	20	30
ENNV	ENCELIOPSIS nudicaulis	BARESTEM ENCELIOPSIS	SW	109	10	10	101	0	40	102	50	0			
				103	80	80							4	35	32
			NW	3	40	70	5	50	80				2	45	75
EPILO	EPILOBIUM	WILLOW HERB	SW	109	10	20	101	25	30	102	10	20			
				103	15	10							4	15	20
			NW	3	10	20	4	0	20	5	10	10			
				107	0	10	70	20	70				5	8	26
	E. adenocaulon	Sticky willowweed		3	10	20							1	10	20
EPAN2	E. angustifolium	Fireweed	SW	109	30	60							1	30	60
			GP	108	20	60							1	20	60
			NW	3	30	60	4	30	65	107	30	70			
				71	20	50							4	28	61
EPPA2	E. paniculatum	Autumn willowweed		3	10	20							1	10	20
ERIGE2	ERIGERON	FLEABANE	SW	109	20	20	101	15	15	102	0	15			

PROPER USE FACTORS FORBS (cont.)

ERIGE2	Erigeron	Fleabone	SW	103	15	10							1	12	15
			NW	107	10	10	71	10	30	6	10	10			
				7	20	10	70	20	30				5	14	18
ERACD	E. acris devilis	Bitter fleabone		3	0	10							1	0	10
	E. asper			3	10	40							1	10	40
ERCA2	E. caespitosus	Tufted fleabone		3	10	20							1	10	20
ERCO4	E. compositus	Fernleaf fleabone		3	10	20							1	10	20
ERDI4	E. divergens	Spreading fleabone		3	0	10							1	0	10
ERFO3	E. formosissimus	Fleabone		3	0	10							1	0	10
	E. macranthus	Aspen fleabone		3	10	40							1	10	40
	E. salsuginosus	Aster fleabone		3	10	40							1	10	40
ERIOG	ERIOGONUM			101	15	15	102	15	15	103	15	15	3	15	15
ERIOG	Eriogonum	Eriogonum	SW	109	10	20	101	15	15	102	20	10			
				103	15	20							4	15	16
			NW	107	0	10	6	10	10	7	10	10			
				71	0	10	70	0	40				5	4	16
	E. cereum	Nodding eriogonum		3	0	10							1	0	10
ERCO12	E. compositum	Buckwheat		3	0	10							1	0	10
ERGR6	E. gracillimum			109	10	20							1	10	20
ERHE2	E. heracleoides	Buckwheat		3	0	10	71	5	10				2	2	10
ERMI4	E. microthecum	Slender buckwheat		3	0	10							1	0	10
ERNU3	E. nudum	Tribinagua		109	30	40							1	30	40
EROV02	E. ochroleucum	Buckwheat		3	0	10							1	0	10
	E. orthocaulon	Buckwheat		3	0	10							1	0	10
EROV	E. ovalifolium	Cushion eriogonum	SW	109	10	10	101	15	15	102	20	10			
				103	15	20							4	15	14
			NW	3	15	15	4	15	10				2	15	12
	E. stellatum	Longray eriogonum		3	0	10							1	0	10
ERSTP	E. subalpinum	Subalpine eriogonum		3	0	10							1	0	10
ERUM	E. umbellatum	Sulpher flower	SW	109	10	10							1	10	10
			NW	3	10	20	4	10	20				2	10	20
ERVI5	E. vimineum	Broom eriogonum		3	10	30	4	10	20				2	10	25
ERVI6	E. virgatum			109	10	20							1	10	20
ERWA3	E. watsonii			3	10	20	4	10	20				2	10	20
ERIOP2	ERIOPHYLLUM	WOOLY LEAF	SW	109	10	20							1	10	20
			NW	107	0	10	70	0	40				2	0	25
ERLA6	E. lanatum	Wooly eriophyllum		71	0	10							1	0	10
	ERITRICHIUM	MT. FORGET-ME-NOT		70	20	40							1	20	40
ERODI	ERODIUM	ALFILERIA		70	40	80							1	40	80
ERBO	E. botrys	Broadleaf filaree		109	60	80							1	60	60
ERCI6	E. cicutarium	Redstem filaree	SW	109	80	80	101	60	60	102	25	60			
				103	60	40							4	74	65
			NW	3	60	60	4	10	40	5	75	40			
				71	40	60	6	50	10	7	50	20	5	57	42
ERMO7	E. moschatum	White stem filaree		109	70	50							1	70	50
ERYSI	ERYSIMUM	HEDGE MUSTARD		70	10	40							1	10	40
ERAS2	E. asperum	Western wallflower	SW	109	10	10							1	10	10
			GP	108	10	40							1	10	40
ERFR3	E. franciscanium			109	10	10							1	10	10
	E. parviflorum			3	0	10							1	0	10
	ERYTHRONIUM	DOGTOOTH VIOLET		70	20	30							1	20	30
	E. parviflorum	Dogtooth violet		107	0	10							1	0	10
	ESCHSCHOLTZIA	CALIFORNIA POPPY		109	0	10							1	0	10
FRAGA	FRAGARIA	STRAWBERRY		3	0	10	107	10	20	6	10	10			

PROPER USE FACTORS FORBS (cont.)

FRAGA	Fragaria	Strawberry		7	20	10	71	0	10	70	0	20	6	7	13
FRVEA	F. americana	Strawberry		3	0	10							1	0	10
FRCA	F. californica	Wood strawberry		109	20	30							1	20	30
FRCH	F. chilensis	Sand strawberry		109	20	30							1	20	30
	F. glauca	Blueleaf strawberry		3	0	10							1	0	10
FRVIO	F. platy petala	Broadleaf strawberry		101	10	5	102	0	40	103	40	0	3	17	15
	F. birginiana	Scarlet strawberry	SW	109	30	30							1	30	30
			NW	3	5	20	4	10	20				2	8	20
FRGR	FRANKENIA grandifolia	ALKALI HEATH		109	20	20							1	20	20
FRANS	FRANSERIA	BURSAGE		109	10	10							1	10	10
FRAC	F. acanthicarpa	Bursage		109	20	30							1	20	30
FRASE	FRASERA	ELKWEED		3	0	10	107	0	20	70	10	30	3	3	20
FRALN	F. nitida	Shiny frasera		71	10	20							1	10	20
FRMO	F. montana	Elkweed		3	10	20							1	10	20
FRSP	F. speciosa	Elkweed	SW	101	5	5	102	0	25	103	25	0	3	10	10
			NW	3	10	20	4	5	20	71	10	20	3	8	20
FRITI	FRITILLARIA	FRITILLARY		70	20	30							1	20	30
FRAT	F. atropurpurea	Spotted fritillary	SW	102	0	10	103	10	0				2	5	5
			NW	3	0	10							1	0	10
GAIL	GAILLARDIA	BROWN-EYED SUSAN		70	0	20							1	0	20
GAAR	G. aristata	Brown-eyed Susan	GP	69	10	10							1	10	10
			NW	3	0	20	107	0	20				2	0	20
GALIU	GALIUM	BEDSTRAW	SW	109	0	10							1	0	10
			NW	3	0	10	71	0	10	70	10	30	3	3	17
GAAP2	G. aparine	Catchweed bedstraw		3	0	10							1	0	10
GABO2	G. boreale	Northern bedstraw		3	0	10	71	0	10				2	0	10
GAMU2	G. multiflorum	Shrubby bedstraw		3	0	10							1	0	10
GAURA	GAURA	GAURA		70	0	60							1	0	60
	GAYOPAHTUM ramosissmum	KITCHEN WEED		109	10	10	102	0	10				2	5	10
GENTI	GENTIANA	GENTIAN	SW	109	10	20							1	10	20
			NW	3	10	20	71	0	50	70	10	20	3	7	30
	G. affinis	Rocky Mt. gentian		3	10	20							1	10	20
GEHO	G. holopetala	Fringed gentian		109	10	20							1	10	20
GERAN	GERANIUM	CRANESBILL	SW	109	30	50	101	35	35	102	0	45			
				103	55	0							4	30	32
			GP	108	40	60							1	40	60
			NW	3	30	50	4	20	40	107	20	40			
				6	30	20	7	40	40	71	20	40			
				70	40	60	38	25	45	39	12	22			
				40	25	45	41	12	22	42	25	45			
				43	12	22	44	22	37	45	12	17			
				46	17	32	47	12	17	48	17	25			
				49	12	17	50	25	45	51	12	22			
				52	25	45	53	12	22	54	22	37			
				55	12	17	56	17	32	57	12	17			
				58	17	25	59	25	45	60	12	22			
				61	25	45	62	12	22	63	22	37			
				64	12	17	65	17	32	66	12	17			
				67	17	25	68	12	17	72	25	45			
				73	12	22	74	25	45	75	12	22			
				76	22	37	77	12	17	78	17	32			
				79	12	17	80	17	25	81	25	45			
				82	12	22	83	25	45	84	12	22			
				85	22	37	86	12	17	87	17	32			

PROPER USE FACTORS — FORBS (cont.)

GERAN	Geranium	Cranesbill	NW	88 12 17	89 17 25	90 12 17	
				91 25 45	92 12 22	93 25 45	
				94 12 22	95 22 37	96 12 17	
				97 12 32	98 12 17	99 17 25	
				100 12 17			
GEBI2	G. bicknellii	Bicknell geranium		69 30 50			1 30 50
GEFR2	G. fremonti	Fremont geranium		3 20 40			1 20 40
	G. incisum	Cleftleaf geranium		109 40 60			1 40 60
GERI	G. richardsonii	Richardson geranium	GP	69 30 50			1 30 50
			NW	3 20 40	107 20 40		2 20 40
GEVI2	G. viscosissimum	Sticky geranium	SW	109 40 50	101 35 35	102 0 45	
				103 55 0			4 32 32
			GP	69 30 50			1 30 50
			NW	3 30 50	4 20 40	107 20 40	
				71 20 40			4 22 42
GEUM+	GEUM	AVENS	GP	108 10 30			1 10 30
			NW	107 0 20	70 20 30		2 10 25
GEMA4	G. macrophyllum	Bigleaf avens		3 0 20	71 20 25		2 10 22
GETR	G. triflorum	Prairie smokeavens		71 10 40			1 10 40
GILIA	GILIA	GILIA	SW	109 0 10	102 0 25	103 25 10	3 8 15
			NW	107 0 20			1 0 20
	GILIA (was Columia spp.)			109 10 20			1 10 20
	GILIA (was Leptodactylon spp.)			109 10 10			1 10 10
GIAG	G. aggregata	Scarlet trumpet	SW	102 0 25	103 25 10		2 12 13
			NW	3 0 20	4 0 20	5 0 10	3 0 17
	G. linearis	Slender leaved gilia		109 20 30			1 20 30
GLHE	GLECOMA hederacea	GROUND IVY		109 0 10			1 0 10
GLLE3	GLYCYRRHIZA lepidota	AMERICAN LICORICE	SW	102 0 10	103 10 0		2 5 5
			NW	3 0 10	4 0 10	5 0 10	3 0 10
GODET	GODETIA	GODETIA		109 0 10			1 0 10
GRIND	GRINDELIA	GUMPLANT		101 0 5	102 0 15	103 15 0	3 5 7
GRWA	G. nana	Low gumweed		71 5 0			1 5 0
HABEN	HABENARIA	HABE NARIA		71 10 20			1 10 20
	HACKELIA florribunch	THICKET STICKSEED	SW	109 10 20			1 10 20
			NW	70 0 10			1 0 10
	HALERPESTES	TRAILING BUTTERCUP		70 0 70			1 0 70
	HAPLOPAPPUS boreale	NORTHERN SWEETVETCH		3 30 50	4 45 65	5 40 40	3 38 52
HEDEO	HEDEOMA	PENNYROYAL		70 20 40			1 20 40
HEDYS	HEDYSARUM	SWEETVETCH	SW	109 10 10	101 45 50	102 40 65	
				103 60 40			4 39 41
			GP	108 30 60			1 30 60
			NW	3 30 50	4 45 65	5 40 40	
				107 60 60	70 50 60		5 51 59
HEAL	H. alpinum			69 20 40			1 20 40
HEDYS	HELENIUM hoopesii	ORANGE SNEEZEWEED		109 P F	101 10 0	102 0 40	
				103 40 0			4 12 10
HELIA	HELIANTHELLA	LITTLE SUNFLOWER	SW	109 20 40			1 20 40
			GP	108 10 20			1 10 20
			NW	70 10 30			1 10 30
HECA	H. californica	Little sunflower		109 10 10			1 10 10
	H. douglasii	Little sunflower		107 10 40	71 20 40		2 15 40
	H. erinervata	Little sunflower		3 20 40			1 20 40
HEUN	H. uniflora	Oneflower helianthella	SW	109 40 50	101 45 35	102 0 55	
				103 45 20			[illegible] 32 40

PROPER USE FACTORS — FORBS (cont.)

HEUN	H. uniflora	Oneflower helianthella	NW	3	20	40	4	10	40	5	0	20			
				107	10	40	71	20	40				5	12	36
HELIA3	HELIANTHUS	SUNFLOWER	SW	109	10	10							1	10	10
			NW	70	10	30							1	10	30
HEAN3	H. annuus	Common sunflower	SW	109	10	10	102	10	0	103	0	10	3	[illegible]	7
			GP	108	10	20							1	10	20
			NW	71	10	20							1	10	20
	H. aridus	Sunflower		3	10	10							1	10	10
	H. fascicularis	Sunflower		3	10	10							1	10	10
	H. maximilianus	Maximilian sunflower		3	10	10							1	10	10
HENU	H. nuttallii		GP	69	10	20							1	10	20
			NW	3	10	10							1	10	10
HEPE	H. petiolaris	Prairie sunflower		69	10	20							1	10	20
HELE	H. sabrhomboideus	Rhombic leaf sunflower		69	10	20							1	10	20
HEMIZ	HEMIZONIA	TARWEED		109	10	20							1	10	20
HERAC	HERACLEUM	COW PARSNIP		70	30	70							1	30	70
HELA4	H. lanatum	Common cow parsnip	SW	109	40	70	101	50	50	102	0	55			
				103	55	0							4	36	44
			NW	3	50	70	4	20	75	107	70	70			
				71	50	60							4	48	66
HEUCH	HEUCHERA	ALUM ROOT	SW	109	0	10							1	0	10
			NW	107	20	20	71	0	10	70	0	10	3	7	13
	H. cylindrica	Roundleaf alumroot		3	0	10							1	0	10
HEGL4	H. glabella	Alumroot		3	0	10							1	0	10
HIERA	HIERACIUM	HAWKWEED		70	50	80							1	50	80
HIAL	H. albertinum	Woolyweed		3	40	70							1	40	70
HIAL2	H. albiflorum	White hawkweed		71	5	10	3	50	80				2	28	45
	H. columbianum	Hawkweed		3	40	70							1	40	70
HICY	H. cynoglossoides	Woolywood		109	10	30							1	10	30
HISC2	H. scouleri	Hawkweed	SW	109	10	10	101	35	40	102	20	40			
				103	50	20							4	29	28
			NW	3	40	70	4	5	20	71	20	35	3	22	42
	HOOKERA	WILD HYACINTH		70	20	80							1	20	80
	H. douglasii	Douglas brodia		102	0	10	103	15	0				2	8	5
HOFU	HORKELIA fusca	TAWNY HAWKELIA		101	55	55	102	0	60	103	60	0	3	38	38
	HYDROPHYLLUM albifrons	WHITEFACE WATERLEAF		3	10	10							1	10	10
HYCA4	H. capitatum	Cat's breeches	SW	109	30	50							1	30	50
			NW	3	20	50	4	15	15	71	10	30	3	15	32
HYFEA	H. fendleri albifrons	Whiteface fendler waterleaf		71	10	20							1	10	20
HYMEN4	HYMENOPAPPUS		SW	101	0	5	103	5	0				2	2	2
			NW	3	5	5	70	0	10				2	2	8
HYPE	HYPERICUM perforatum	COMMON ST. JOHNSWORT		71	P	P							1	P	P
	H. scouleri	Scouler St.Johnswort		3	P	P							1	P	P
HYRA3	HYPOCHOERIS radicata	HAIRY CAT'S EAR		109	20	20							1	20	20
IRIS+	IRIS	FLAG		109	10	10							1	10	10
IRLO	I. longipetala	Coast iris		109	10	10							1	10	10
IRMI	I. missouriensis	Western blue flag		109	10	10	101	0	10				2	5	10
	IVESIA	IVESIA		70	0	10							1	0	10
	KOCHIA vestita	GRAY SUMMER CYPRESS		3	20	30	4	10	30	5	10	20	3	13	27
	LACINIARIA punctata	BLAZING STAR	GP	108	0	60							1	0	60
			NW	70	0	60							1	0	60
LACTU	LACTUCA	LETTUCE	SW	109	30	40	101	65	50	102	15	10			
				103	40	15							4	38	36

PROPER USE FACTORS — FORBS (cont.)

LACTU	Lactuca	Lettuce	NW	3 30 50	4 30 50	5 15 15	
				107 50 60	6 20 20	7 50 40	
				70 20 70			7 31 44
LACA	L. canadensis	Canada lettuce		3 30 50	4 30 50		2 30 50
	L. integrata	Wild lettuce		3 30 50	4 30 50		2 30 50
LAPU	L. pulchella	Chicory lettuce		3 30 50	4 30 50		2 30 50
	S. scariola			3 30 50	4 20 40	5 10 15	3 20 35
LASA	L. scariola	Prickly lettuce	SW	109 20 30	101 0 20	102 10 40	
				103 45 15			4 19 26
			GP	108 20 70			1 20 70
			NW	3 30 50	4 30 50	5 10 15	
				71 20 40			4 22 39
LAPPU	LAPPULA	STICKSEED	SW	109 0 10	101 5 15	102 0 20	
				103 15 0			4 5 11
			NW	71 0 10	70 0 10		2 0 10
	L. florribunda	Thicket stickseed	SW	109 10 20	101 10 15	102 0 30	
				103 15 0			4 9 16
			NW	3 0 10	4 10 30		2 5 20
	L. occidentalis	Stickseed	SW	101 10 15	102 0 30	103 15 0	3 8 15
			NW	3 0 10			1 0 10
LARE	L. redowski	Western stickseed		71 0 10			1 0 10
	L. subdecumbens	Stickseed	SW	109 40 40	101 0 10	103 20 0	3 20 17
			NW	3 0 10	4 0 10		2 0 10
LATHY	LATHYRUS	PEAVINE	SW	109 40 60	101 20 20	102 0 15	
				103 30 0			4 22 24
			NW	3 40 50	4 10 10	107 10 40	
				71 30 40	70 50 60		5 28 44
LABI2	L. bijugatus	Sandberg peavine		107 10 40			1 10 40
	L. obovatus	Ovalleaf peavine		3 40 50	4 10 10		2 25 30
LAOC2	L. ochroleucus	Cream peavine		59 30 50			1 30 50
LAVE	L. venosus	Veiny peavine		69 30 50			1 30 50
LAYIA	LAYIA	TIDY TIPS		109 10 20			1 10 20
	LEONTODON	DANDELION		70 50 80			1 50 80
	L. taraxacum	Dandelion	SW	101 30 65	102 70 80	103 80 75	3 70 73
			GP	108 50 70			1 50 70
LEPID	LEPIDIUM	PEPPER GRASS	SW	109 10 10			1 10 10
			NW	3 40 50	6 30 10	7 40 0	
				71 10 20			4 30 20
	L. apetalum	Pepperweed		3 40 50			1 40 50
LEPTO	LEPTODACTYLON			101 10 30	102 10 10	103 30 10	
				109 10 10			4 15 15
	LEPTOTAENIA	CARROTLEAF		70 0 20			1 0 20
	L. dissecta	Carrotleaf		109 30 50			1 30 50
	L. multifida	Carrotleaf	SW	101 15 25	102 5 25	103 55 5	3 25 18
			NW	3 30 50	4 15 10	5 5 5	
				107 20 50	6 30 10	7 50 30	
				71 20 40			7 21 32
	LESSINGIA glandulifera	Lessingia		109 10 10			1 10 10
LEUCO	LEUCOCRINUM	MOUNTAIN LILY		70 10 70			1 10 70
LEMO4	L. montanum	Mountain lily		108 10 10			1 10 10
LEWIS	LEWISIA	LEWISIA		109 10 30			1 10 20
LIATR	LIATRIS	BLAZING STAR		70 0 10			1 0 10
LIPU	L. punctata	Blazing star		108 0 10	59 55 55		2 28 32
LIGUS	LIGUSTICUM	LOVAGE	SW	109 50 70	101 30 60	102 0 50	

PROPER USE FACTORS FORBS (cont.)

LIGUS	Ligusticum	Lovage	SW	103	70	0							1	30	45
			IW	3	50	70	4	5	50	107	40	60			
				71	0	40	70	10	60				5	23	60
LICA2	L. canbyi	Lovage		3	70	80							1	70	80
LIFI	L. filicinum	Fernleaf loveroot		3	70	80							1	70	80
LIVE	L. verticillatum			3	70	80							1	70	80
LILIU	LILIUM	LILY		71	0	20	70	20	80				2	10	50
	LIMNORCHIS	BOG ORCHID		70	0	80							1	0	80
LIUM	LINUM	FLAX		70	20	30							1	20	30
LIPEL	L. lewisii	Blueflax	SW	109	10	30	102	0	10	103	20	35	3	10	25
			GP	108	10	20							1	10	20
			IW	3	10	20	4	0	10	5	0	35			
				107	0	10							4	2	19
LIPPI	LIPPIA	LEMON VERBENA		109	40	50							1	40	50
LITHO2	LITHOPHRAGMA	WOODLAND STAR	SW	109	0	10	102	0	5	103	5	0	3	2	5
			IW	107	0	10	70	0	80				2	0	45
LIPA5	L. parviflora	Woodland star	SW	102	0	5	103	5	0				2	2	2
			IW	3	0	5	4	0	5				2	0	5
LITE4	L. tenella	Slender woodland star	SW	102	0	5	103	5	0				2	2	2
			IW	3	0	5	4	0	5				2	0	5
LITHO3	LITHOSPERMUM	STONESEED	SW	101	45	45	102	15	55	103	15	15	3	35	38
			IW	70	0	10							1	0	10
LIRV4	L. ruderale	Puccoon	SW	109	20	20	101	45	45	102	15	55			
				103	45	15							4	31	34
			IW	3	20	20	4	0	30	5	15	15	3	12	22
LOMAT	LOMATIUM	HOG-FENNEL	SW	109	20	40							1	20	40
			IW	3	40	70	107	30	50	6	30	0			
				7	40	0	71	30	50				5	34	34
LOMAT	LOMATIUM			109	10	30							1	10	30
LOAM	L. ambiguum	Wyeth buiscuitroot		3	40	70							1	40	70
LOGE2	L. geyeri	Geyer biscuitfoot		71	30	50							1	30	50
LOGR	L. grayii	Buiscuitroot		3	40	70							1	40	70
LOMA3	L. macrocarpum	Bigseed lomatium		3	40	70							1	40	70
	L. nudicaule	Barestem lomatium	SW	109	10	20							1	10	20
			IW	71	10	20							1	10	20
	L. platyocarpum	Buiscuitroot		3	40	70							1	40	70
	L. platyphyllum	Buiscuitroot		3	25	25							1	25	25
	L. parparcum	Buiscuitroot		3	40	70							1	40	70
LOTR2	L. triternatum	Nineleaf lomatium		3	40	70	71	30	50				2	35	60
LOTUS	LOTUS	DEER VETCH	SW	109	30	40	101	15	15	102	10	35			
				103	35	60							4	22	36
			IW	3	50	60	4	15	35	5	10	50			
				71	50	60							4	31	51
	L. americanus	Spanish clover	SW	109	30	50							1	30	50
			IW	3	50	60							1	50	60
LODO3	L. douglasii	Douglas deervetch		3	50	60							1	50	60
LOHV2	L. humistratus	Hill lotus		109	40	60							1	40	60
LOMI	L. micranthus	Littleflower deervetch		109	40	50							1	40	50
LOSU3	L. subpinnatus	Chilean deervetch		109	40	60							1	40	60
LUPIN	LUPINUS			3	20	40	107	20	40	6	20	20			
				7	30	20	71	20	40	70	40	60	6	25	37
LUPIN	LUPINUS	SILVER LUPINE	SW	109	40	20	101	20	25	102	20	35			
				103	35	45							4	21	31
			GP	108	10	40							1	10	40
			IW	3	10	20	4	10	20	5	10	20			

			PROPER USE FACTORS				FORBS (cont.)
LUPIN	Lupinus	Silver lupine	NW	6 10 10	7 20 20	71 10 20	3 12 13
LUAR3	L. argenteus	Silvery lupine	GP	69 0 40			1 0 40
			NW	3 P P			1 P P
LUBR3	L. breweri	Brewer lupine		109 40 60			1 40 60
	L. barkei	Burke lupine		71 30 40			1 30 40
LUPO2	L. caespitosus	Stemless lupine		109 10 20			1 10 20
LUCA	L. caudatus	Tailcup lupine	SW	109 20 40			1 20 40
			NW	3 25 35	4 20 35	5 20 45	
				71 5 20			4 18 34
LULE3	L. leucophyllus	Velvet lupine		3 20 40	71 30 60		2 25 50
LULE2	L. lyalli	Lyall lupine		109 10 20			1 10 20
LUSU5	L. ornatus	Ornate lupine		3 10 20			1 10 20
LUSE4	L. seriecus	Silky lupine		3 10 20			1 10 20
LUSU5	L. sulphureus	Sulpher lupine		71 5 30			1 5 30
	LYTHRUM hyssopifolia	GRASS POLY		109 10 10			1 10 10
	MACHAERANTHERA			70 10 40			1 10 40
MALVA	MALVA	MALLOW	SW	109 20 20			1 20 20
			NW	70 0 20			1 0 20
MARO	M. rotundifolia	Dwarf mallow	SW	109 0 10			1 0 10
			GP	108 0 10			1 0 10
			NW	3 0 10	107 0 10	71 0 10	3 0 10
MALVA2	MALVASTRUM coccineum	SCARLET GLOBEMALLOW		108 0 10			1 0 10
	MARRUBIUM	HOREHOUND		70 0 10			1 0 10
	M. vulgare	Common horehound	SW	109 10 10			1 10 10
			NW	3 0 10			1 0 10
MEDIC	MEDICAGO	MEDICK		70 80 80			1 80 80
MEHI	M. hispida	Burclover		109 80 80			1 80 80
MELV	M. lupulina	Black medick	SW	109 60 60			1 60 60
			NW	3 60 60	107 70 70		2 65 65
MESA	M. sativa	Alfalfa	SW	109 80 80	101 80 80	102 80 80	
				103 80 80			4 80 80
			NW	3 80 80	4 80 80	5 80 80	
				107 80 80			1 80 80
MELIL	MELILOTUS	SWEETCLOVER	SW	101 60 70	102 60 60	103 70 40	3 63 57
			GP	108 50 40			1 50 40
			NW	3 20 30	4 60 60	5 60 40	
				107 60 60	6 50 50	7 30 50	
				71 20 30	70 80 80		8 48 50
MEAL2	M. alba	White sweetclover	SW	109 30 50			1 30 50
			GP	69 60 40			1 60 40
			NW	3 40 40	4 40 40	107 60 60	3 47 47
MEIN2	M. indica	Yellow sweet clover		109 30 40			1 30 40
MEOF	M. officinalis	Yellow sweetclover	SW	109 40 60			1 40 60
			GP	69 60 40			1 60 40
			NW	3 40 40	4 40 40	107 60 60	3 47 47
MENTH	MENTHA	MINT	SW	109 10 20	101 10 10	102 0 25	
				103 20 0			4 10 14
			NW	3 10 20	4 10 25	107 10 20	
				6 10 10	7 20 20	70 20 10	6 13 22
MEAR4	M. arvensis	Fieldmint		3 10 20			1 10 20
	M. penardi	Canada mint	NW	71 10 20			1 10 20
			SW	109 10 20			1 10 20
MESP3	M. spicata	Spearmint		3 10 20			1 10 20
MERTE	MERTENSIA	LUNGWORT	SW	109 30 50	101 10 10	102 0 70	

PROPER USE FACTORS — FORBS (cont.)

MERTE	Mertensia	Lungwort	SW	103 50 0			1 50 40
			GP	108 50 70			1 50 70
			IM	3 30 50	4 20 50	71 20 50	
				70 20 80			4 22 58
	M. ciliosa	Bluebells		3 40 60	107 40 70		2 40 65
MELO4	M. longiflora	Small bluebell		3 30 60	107 20 40	5 20 0	
				7 40 0			4 28 25
MEPA	M. paniculata	Panicle bluebell		3 20 50			1 20 50
	M. pulchella	Small bluebell		3 10 40			1 10 40
	MICRANTHES			70 10 20			1 10 20
MICRO6	MICROSERIS	MICROSERIS		109 10 10			1 10 10
MINU	M. nutans	Nodding microseris		3 20 40			1 20 40
MIMUL	MIMULUS	MONKEY FLOWER	SW	109 10 10	101 10 10	102 0 20	
				103 20 0			4 10 10
			IM	70 20 40			1 20 40
MIGU	M. guttatus	Common monkeyflower	SW	101 10 10	102 0 20	103 20 5	3 10 12
			IM	3 10 20	4 10 20	5 0 5	3 7 15
MILE2	M. lewisii	Lewis monkeyflower	SW	102 0 30			1 0 30
			IM	4 0 30	71 10 40		2 5 35
	MIRABILIS multiflorum	Four o'clock		109 0 30			1 0 30
MITEL	MITELLA	MITEWORT		71 0 10	70 10 20		2 5 15
MIPE	M. pentandra	Fivestamen mitewort		107 10 40			1 10 40
MONAR	MONARDA	BEEBALM		70 20 40			1 20 40
MOFI	M. fistulosa	Beebalm		3 10 40			1 10 40
MONAR2	MONARDELLA	MINT		109 10 30			1 10 30
MOOD	M. odoratissima	Pungent pennyroyal		4 5 5			1 5 5
MONU	MONOLEPIS nuttaliana	PATATA	GP	108 20 30			1 20 30
			IW	3 10 20			1 10 20
MONU	M. nuttalliana	Poverty weed		3 10 20			1 10 20
MONTI	MONTIA	INDIAN LETTUCE		71 10 20			1 10 20
MOLI4	M. linearis	Indian lettuce		3 10 20	107 10 30		2 10 25
MOPA2	M. parviflora	Small leaved montia		3 10 20			1 10 20
MOPE2	M. perfoliata	Miner's lettuce	SW	109 10 20			1 10 20
			IW	3 10 20			1 10 20
MYOSO	MYOSOTIS	FORGET-ME-NOT		70 20 40			1 20 40
MYAL	M. alpestris	Forget-me-not		108 20 40			1 20 40
NEMOP	NEMOPHILA	NEMOPHILA		109 0 10			1 0 10
NEME	N. menziesii	Baby blue eyes		109 0 10			1 0 10
NEPET	NEPETA	CATNIP		70 20 40			1 20 40
NECA2	N. cataria	Catnip	SW	109 0 20			1 0 20
			IW	3 10 20			1 10 20
	N. hederacea	Ground ivy		109 0 10			1 0 10
NIOC2	NITROPHILA occidentalis			109 0 10			1 0 10
	NORTA altissima	TUMBLEMUSTARD		101 0 10	102 10 15	103 15 15	3 8 13
	OENOGRA pallida	WHITE EVENING PRIMROSE		108 10 20			1 10 20
OENOT	OENOTHERA	EVENING PRIMROSE	SW	109 10 20			1 10 20
			IM	107 10 20	70 0 60		2 5 40
OECA	O. caespitosa	Tufted evening primrose		3 5 10			1 5 10
OEHE	O. heterantha	Sandrops		3 10 20			1 10 20
OEHO	O. hookeri	Hooker evening primrose		3 10 20	71 10 20		2 10 20
OEPA	O. pallida	Pale evening primrose		3 10 20			1 10 20
OESL	O. scapoidea			3 10 10			1 10 10

PROPER USE FACTORS FORBS (cont.)

OEST2	O. strigosa			3	10	20							1	10	20
	O. subacaulis			3	20	45	4	20	45				2	20	45
	OREOCARYA	HAIRY LEAF	SW	102	0	5	103	5	0				2	2	2
			IM	70	0	10							1	0	10
	OROGENIA linearifolia	INDIAN POTATO		109	20	20	101	15	20	102	0	30			
				103	50	0							4	21	18
ORTHO	ORTHOCARPUS	OWL'S CLOVER	SW	109	10	10							1	10	10
			IM	70	0	20							1	0	20
OSMOR	OSMORHIZA	SWEET CICELY	SW	109	60	70							1	60	70
			IM	107	50	80	71	40	60	70	10	80	3	33	73
	O. divaricata	Spreading sweetroot	SW	101	50	50	102	0	75	103	75	0	3	42	42
			IM	3	40	60	4	30	40	5	40	70			
				71	40	60							4	38	58
OSOB	O. obtusa	Sweetroot	SW	101	60	70	102	0	75	103	80	0	3	47	48
			IM	3	40	70	4	30	40				2	35	55
OSOC	O. occidentalis	Sweet-anise	SW	101	60	65	102	0	75	103	80	0	3	47	47
			IM	3	40	70	4	30	70	5	40	70			
				71	40	60							4	38	68
OXALI	OXALIS corniculata	YELLOW SORREL		109	10	10							1	10	10
OXYRI	OXYRIA digyna	MOUNTAIN SORREL		71	0	10							1	0	10
OXPE2	OXYTHECA perfoliata	THOROWORT OXYTHECA		109	10	10							1	10	10
OXYTR	OXYTROPIS	LOCOWEED	SW	109	P	P							1	P	P
			GP	108	0	20							1	0	20
			IM	70	0	20							1	0	20
	PACHYLOPHUS	STEMLESS EVENING PRIMROSE	SW	101	10	5	102	0	20	103	10	5	3	7	10
			IM	70	0	20							1	0	20
PAEON	PAEONIA	PAEONIA		70	0	10							1	0	10
PABR	P. brownii	Western peony	SW	109	30	40	101	10	10	102	0	30			
				103	40	0							4	20	20
			IM	3	10	40	4	0	30	71	10	40	3	7	37
PASTI	PASTINACA	PARSNIP		70	40	60							1	40	60
PASA2	P. sativa	Common parsnip		109	10	20							1	10	20
PEDIC	PEDICULARIS	LOUSE WORT	SW	109	10	10	101	10	10	102	0	20			
				103	20	0							4	10	10
			IM	3	10	20	107	10	20	71	0	10			
				70	0	10							4	5	15
PEBR	P. bracteosa	Northern fernleaf		3	0	10							1	0	10
PECO	P. contorta	Coiled pedicularis		71	0	30							1	0	30
	P. groenlandica	Elephanthead		3	0	10	71	0	30				2	0	20
PERA	P. racemosa	Sickletop		3	0	10							1	0	10
PEWTS	PENTSTEMON	PENTSTEMON	SW	109	10	20	101	5	10	102	10	15			
				103	20	10							4	11	14
			GP	108	10	20							1	10	20
			IM	3	10	20	4	5	15	107	10	20			
				6	10	10	7	20	10	71	15	40			
				70	20	30							7	13	21
PEAC	P. acuminatus	Sharpleaf pentstemon		3	0	10							1	0	10
PEAL2	P. albidus	White pentstemon		69	10	20							1	10	20
PECO6	P. confertus	Yellow pentstemon		3	0	10	71	25	10				2	12	10
	P. deustus	Scabland pentstemon		3	0	10							1	0	10
PEER	P. eriantherus	Fuzzytongue pentstemon		3	0	10							1	0	10
PEGL3	P. glaber	Sawsepal pentstemon		3	0	10							1	0	10
PEGL4	P. glandulosus	Stickystem pentstemon		3	0	10							1	0	10
PEGR5	P. gracilis	Slender pentstemon		69	10	20							1	10	20

	P. nitidus	Waxleaf pentstemon		69	10	20							1	10	10
	P. oratus			3	0	10							1	0	10
PEPR2	P. procerus	Littleflower pent-	GP	69	10	20							1	10	20
		stemon	NW	71	0	10							1	0	10
PERY	P. rydbergii	Rydberg pentstemon		3	10	20							1	10	20
	P. scouleri	Scouler pentstemon		3	0	10							1	0	10
	P. speciosus	Royal pentstemon		3	0	10							1	0	10
	PERAPHYLLUM ramosissimum	SQUAW-APPLE		101	25	5	102	15	10	103	40	20	3	27	22
	PERIDERIDIA gairdneri	SQUAW ROOT	SW	109	30	40							1	30	40
			NW	107	70	70							1	70	70
PETAL2	PETALOSTEMON	PRAIRIE CLOVER		70	0	20							1	0	20
	P. candidus	White prairieclover		69	10	20							1	10	20
	P. oligophyllus	Prairie clover		101	20	40							1	20	40
PEPU6	P. purpurens	Purple prairieclover		69	10	20							1	10	20
PHACE	PHACELIA	FIDDLENECK	SW	109	10	30	101	15	15	102	10	60			
				103	60	45							4	31	38
			GP	108	10	20							1	10	20
			NW	107	0	10	6	10	10	7	30	20			
				71	10	20	70	10	20				5	11	16
	P. alpina	Alpine phacelia	SW	109	20	30	101	15	15	102	0	40			
				103	40	0							4	19	21
			NW	3	15	40	4	15	40				2	15	40
PHHE2	P. heterophylla	Varileaf phacelia	SW	109	10	20	101	10	10	102	0	20			
				103	20	10							4	10	15
			NW	3	10	30	4	5	20				2	8	25
PHID	P. idahoensis	Idaho phacelia		3	10	30							1	10	30
	P. leucophylla	Silverleaf phacelia		3	10	30							1	10	30
PHLI	P. linearis	Threadleaf phacelia		3	10	30							1	10	30
PHRA2	P. ramosissima	Branching phacelia	SW	109	50	60	101	50	50	102	0	70			
				103	70	0							4	42	45
			NW	3	10	30	4	5	20				2	8	25
PHSE	P. sericea	Silky phacelia	SW	101	55	55	102	40	70	103	70	0	3	55	[illegible]
			NW	3	10	30	4	5	20	5	20	40	3	12	30
PHLOX	PHLOX	PHLOX	SW	109	10	20	101	10	15	102	20	10			
				103	20	25							4	15	18
			NW	3	10	20	4	10	10	5	20	25			
				107	0	10	6	10	10	7	20	10	6	12	14
	P. canescens	Hoary phlox	SW	109	20	30	101	10	15	102	20	10			
				103	20	25							4	18	20
			NW	3	15	30	4	10	10	5	20	25	3	15	22
	P. canescens	Hoary phlox		3	15	30	4	10	10	5	20	25	3	15	22
PHDO3	P. douglasii	Dwarf Phlox	SW	101	5	14	102	20	5	103	15	25	3	13	15
			NW	3	10	20	5	20	20	70	10	20	3	13	20
PHST2	P. stansburyi	Stansbury phlox		109	20	30	101	10	15	102	20	10			
				103	20	25							4	18	20
	PHYMOSIA	MAPLE-LEAVED MALLOW		70	0	20							1	0	20
PHYSA2	PHYSARIA	TWIN POD	SW	102	0	5	103	5	0				2	2	2
			NW	4	0	5							1	0	5
PHDI16	P. didymocarpa	Common twinpod		102	0	5	103	5	0				2	2	2
PLAGI	PLAGIOBOTHRYS	POPCORN FLOWER		109	10	20							1	10	20
PLANT	PLANTAGO	PLANTAIN	SW	109	10	10	102	0	5	103	10	0	3	7	5
			NW	107	0	30							1	0	30
	P. erecta	Potseed plantain		109	10	10							1	10	10

PROPER USE FACTORS FORBS (cont.)

PLLA	P. lanceolata	English plantain		109 10 20			1 10 20
PLMA2	P. major	Rippleseed plantain		70 0 20			1 0 20
PLPS	P. purshii	Wooly indian wheat	SW	109 0 10			1 0 10
			NW	3 0 10			1 0 10
PLECT	PLECTRITIS	PLECTRITIS		109 10 30			1 10 30
POIN3	POLIOMINTHA incana	HOARY ROSEMARY MINT	SW	109 30 30	101 25 25	102 0 40	
				103 10 10			4 21 34
			NW	3 25 40	4 5 20	5 0 10	3 10 23
POLEM	POLEMONIUM	JACOB'S LADDER	SW	109 10 30			1 10 30
			NW	107 0 20	71 0 10	70 10 20	3 3 17
	P. albiflorum	White polemontum	SW	109 40 50			1 40 50
			NW	3 0 30	4 20 40		2 10 35
	P. columbianum			3 0 30			1 0 30
POFO	P. foliosissimum	Leafty polemontum	SW	109 20 40	101 15 15	102 0 50	
				103 45 0			4 20 25
			NW	3 0 30	4 10 20		2 5 25
POMI	P. micranthum	Minute Jacob's ladder		3 0 30			1 0 30
POOC2	P. occidentale	Western Jacob's ladder		3 0 30			1 0 30
POLYG4	POLYGONUM	KNOTWEED	SW	109 10 20			1 10 20
			GP	108 0 20			1 0 20
			NW	3 0 10	4 0 30	107 10 40	
				71 0 10	70 0 20		5 2 22
POAV	P. aviculare	Wire grass	SW	102 0 10	103 10 0		2 5 5
			NW	3 0 10	4 0 10		2 0 10
POBI6	P. bistortoides	American histort	SW	109 10 30			1 10 30
			NW	3 10 20	70 10 40		2 10 30
POCO10	P. convulvulus	Dullseed cornbind		3 0 10			1 0 10
PODO4	P. douglasii	Douglas knotweed	SW	109 10 20	102 0 10	103 10 0	3 7 10
			NW	3 0 20	4 5 20	71 0 5	3 2 15
POPH	P. phytolaccaefolium	Pokeweed fleeceflower		71 0 10			1 0 10
POWA	P. watsonii	Knotweed		3 0 10			1 0 10
POTEN	POTENTILLA	CINQUEFOIL	SW	109 20 40	101 25 25	102 25 50	
				103 50 50			4 30 44
			GP	108 10 30			1 10 30
			NW	3 10 20	4 10 25	5 25 30	
				107 0 20	71 10 20	70 10 30	6 11 24
POTEN	POTENTILLA	CINQUEFOIL		109 30 20			1 30 20
POAN5	P. anserina	Silverweed cinquefoil	SW	109 40 50	101 25 25	102 25 50	
				103 50 50			4 35 44
			NW	3 25 50	4 10 25	5 25 50	3 20 42
POAR7	P. arguta			69 10 20			1 10 20
	P. bipinnatifida			69 10 20			1 10 20
POGR9	P. blaschkeana	Cinquefoil	SW	109 40 50	101 40 40	102 55 55	
				103 55 55			4 48 50
			NW	3 40 55	4 20 25	5 55 55	3 38 45
	P. corvallaria	Cinquefoil		3 10 20			1 10 20
POGL9	P. glandulosa	Gland cinquefoil		3 10 20	4 20 50		2 15 35
	P. glutinosa			3 10 20	4 15 40		2 12 30
POGR9	P. gracilis	Northwest cinquefoil		3 10 20			1 10 20
PORI3	P. monspeliensis	Montpelier cinquefoil		3 10 20			1 10 20
	P. norregica	Norwegian cinquefoil		69 10 20			1 10 20
	P. perdissecta			3 10 20			1 10 20
	P. viridescens			69 10 20			1 10 20
PRUNE	PRUNELLA	HEALALL		70 20 40			1 20 40

PROPER USE FACTORS FORBS (cont.)

PSATH	PSATHYROTES annua			109 10 10			1 10 10
PSEUD4	PSEUDOCYMOPTERUS	FALSE CYMOPTERUS		70 0 10			1 0 10
	P. bipinnatus			3 40 60			1 40 60
	P. lanceolatus			3 0 10			3 0 10
PSMO	P. montanus	False carrot	SW	109 10 10	102 50 20	103 60 50	3 40 27
			DW	3 40 60	4 0 20	5 50 50	3 30 13
PSORA	PSORALEA	BREADROOT	GP	108 0 10			1 0 10
			DW	71 10 20	70 0 10		2 5 15
PSES	P. esculenta	Indian breadroot		108 0 10			1 0 10
	P. stenostachy	Scurf pea		109 0 10			1 0 10
PTAQ	PTERIDIUM aquilina	BRACKEN		107 0 10			1 0 10
	PTILICALAIA nutans	NODDING MICROSERIS		3 20 10			1 20 10
PULSA	PULSATILLA			70 0 10			1 0 10
	P. hirsatissima	Wild crocus		108 0 10			1 0 10
PYROL	PYROLA	SHINLEAF		3 0 10			1 0 10
	P. bracteata	European pyrola		3 0 10			1 0 10
PYDE	P. dentata	Toothleaf pyrola		3 0 10			1 0 10
PYSE	P. secunda	Sidebells pyrola		3 0 10			1 0 10
	QUAMASIA	CAMAS		70 10 30			1 10 30
	QUAMOCLIDION multiflorum	FOUR O'CLOCK		109 0 30			1 0 30
RANUN	RANUNCULUS	BUTTERCUP	SW	109 10 20	101 30 20	102 0 40	
				103 30 0			1 15 20
			GP	108 10 30			1 10 30
			DW	3 10 30	4 10 20	107 10 30	
				71 10 20	70 10 70		5 10 34
RAAB	R. abortivus	Littleleaf buttercup		3 10 30			1 10 30
RAAL	R. alismaefolius	Plantainleaf buttercup		3 10 30			1 10 30
	R. alismellus	Swarf plantainleaf buttercup		3 10 30			1 10 30
RAUNP	R. bongardi	Bongard buttercup		3 10 30			1 10 30
RACA2	R. californica	California buttercup		109 10 30			1 10 30
	R. cymbararia	Iva buttercup		3 10 30			1 10 30
	R. glaberrimus	Sagebrush buttercup		3 10 30			1 10 30
	R. maximus	Great buttercup		3 10 30			1 10 30
RASC3	R. sceleratus	Rogue buttercup		3 P P			1 P P
	R. sacicola	Buttercup		70 10 70			1 10 70
RATIB	RATIBIDA	SMALL CONE FLOWER		70 0 20			1 0 20
	RHAPHANUS sativus	WILD RADISH		109 0 10			1 0 10
ROLY	RORIPPA nasturtium aquaticum	WATERCRESS		109 40 50			1 40 50
RUDBE	RUDBECKIA	NIGGERHEAD		107 0 20	70 0 20		2 0 20
RUCA3	R. californica	California cone flower		109 10 10			1 10 10
RUOC3	R. occidentalis	Niggerhead	SW	109 20 30	101 0 10	102 0 10	
				103 50 0			4 15 12
			GP	108 0 20			1 0 20
			DW	3 0 30	4 0 20	71 0 20	3 0 13
RUMEX	RUMEX	DOCK	SW	109 20 30	101 10 10	102 5 25	
				103 25 5			1 15 15
			DW	3 10 20	4 10 20	5 5 5	
				107 10 30	6 10 10	7 20 20	
				71 0 10	70 0 50		3 3 19
RUAC3	R. acetosella	Sheep sorrel	SW	109 20 30			1 20 40

PROPER USE FACTORS — FORBS (cont.)

RUAC3	R. acetosella	Sheep sorrel	NW	3	0	10	107	0	10	71	0	10	3	0	10
RUCR	R. crispus	Yellow dock		3	10	20							1	10	20
RUMA4	R. maritimus	Golden dock		3	0	10							1	0	10
RUME2	R. mexicanus	Mexican dock		3	10	20							1	10	20
RUOC3	R. occidentalis	Western dock		3	10	20							1	10	20
RUPA6	R. paucifolius	Mountain sorrel	SW	109	20	30	101	15	10	102	0	30			
				103	45	0							4	20	18
			NW	3	10	20	4	15	30				2	12	25
RUVE2	R. venosus	Sorrel dock	GP	108	10	30							1	10	30
			NW	3	10	20							1	10	20
SARU	SALICORNIA rubra	GLASSWORT		69	10	10							1	10	10
	SALSOLA pestifer	RUSSIAN THISTLE		3	20	20	4	10	10	5	25	25			
				71	5	10							4	15	16
	S. pestifer	Russian thistle	SW	109	20	20	101	10	20	102	25	0			
				103	30	25							4	21	16
			GP	108	20	20	69	20	30				2	20	25
			NW	3	20	20	4	10	10	5	25	25			
				6	30	20	7	30	10				5	23	17
SALVI	SALVIA	SAGE		109	10	10							1	10	10
	SANGUISORBA	BURNET		3	10	20	71	10	20				2	10	20
	S. annua	Prairie burnet		3	10	20	71	10	20				2	10	20
	S. minor	Garden burnet		109	50	60							1	50	60
	S. sitchensis	Sitka burnet		3	10	20	71	10	40				2	10	30
SANIC	SANICULA	SNAKE ROOT		109	10	30							1	10	30
SABI3	S. bipinnatifida	Purple sanicle		109	50	70							1	50	70
	S. menziesii	Gamble weed		109	40	70							1	40	70
	SAPONARIA efficinalis	BOUNCINGBET		3	10	20							1	10	20
SAXIF	SAXIFRAGE	SAXIFRAGE	SW	102	0	10							1	0	10
			NW	4	0	10	71	10	20	70	10	20	3	7	17
	S. arguta	Brook saxifrage		3	10	20	107	10	20				2	10	20
SAME7	S. mertensiana	Mertens saxifrage		3	10	20							1	10	20
SCHOE2	SCHOENOCRAMBE			70	0	10							1	0	10
SCROP	SCROPHULARIA	FIGWORT	SW	109	0	10	102	0	25				2	0	18
			NW	70	0	10							1	0	10
SCUTE	SCUTELLARIA	SKULLCAP		70	0	10							1	0	10
SCAN3	S. angustifolia	Narrowleaf scullcap		3	10	30	71	0	10				2	5	20
SEDUM	SEDUM	STONE CROP	SW	109	0	10							1	0	10
			NW	107	0	10							1	0	10
SEDUM	SEDUM	STONE CROP	SW	102	0	10	103	10	5				2	5	8
			NW	3	0	10	4	0	10	5	0	5	3	0	8
SEST2	S. douglasii	Stonecrop		3	0	10							1	0	10
SEST2	S. stenopetalum	Stonecrop		3	0	10							1	0	10
SENEC	SENECIO	GROUNDSEL	SW	109	10	20	101	20	50	102	10	35			
				103	45	10							4	21	29
			NW	3	10	20	5	10	10	107	20	50			
				6	20	10	7	20	20	71	0	30	6	13	23
SEAU2	S. aureus	Golden ragwort	GP	108	40	70							1	40	70
			NW	70	40	70							1	40	70
SECA2	S. canus	Wooly groundsel	GP	108	10	30							1	10	30
			NW	70	10	30							1	10	30
	S. columbianus	Columbia butterweed	SW	101	5	15	102	0	20	103	25	0	3	10	12
			NW	3	10	50	4	0	20	107	10	50			
				71	0	30							4	5	38
SECR	S. crassulus	Groundsel	SW	101	5	20	102	0	40	103	30	0	3	12	20

PROPER USE FACTORS FORBS (cont.)

SECR	S. crassulus	Groundsel	NW	3 20 30	4 5 40		2 12 35
	S. hydrophyllus	Water groundsel		3 10 20	70 40 70		2 25 45
SEIN2	S. integerrimus	Lamb's tongue groundsel	SW	109 20 30	101 30 35	102 0 55	
				103 50 0			4 25 30
			NW	3 8 30	4 10 40	71 0 30	
				70 40 70			4 12 42
SMEI	S. mikanoides	German ivy		109 20 30			1 20 30
SESE2	S. serra	Butterweed groundsel	SW	109 50 60	101 50 50	102 40 75	
				103 70 60			4 52 61
			NW	3 70 70	4 30 60	5 40 60	
				71 50 50			4 48 65
SETR2	S. triangularis	Arrowleaf butterweed	SW	101 30 30	102 0 60	103 45 0	3 25 30
			GP	108 40 70			1 40 70
			NW	3 30 45	4 10 30	107 50 70	
				71 40 50	70 40 70		5 34 53
	S. vulgaris	Common groundsel		3 10 20			1 10 20
	SESUVIUM sessile	LOWLAND PAISLANE		109 10 10			1 10 10
SIPR	SIBBALDIA procumbens	CREEPING SIBBALDIA		71 5 10			1 5 10
SIHE	SIDA hederacea	ALKALI MALLOW		109 10 10			1 10 10
SIDAL	SIDALCEA	PRAIRIE MALLOW	SW	109 10 10	101 25 10	102 30 30	
				103 35 30			4 25 20
			GP	108 0 10			1 0 10
			NW	3 10 20	5 30 30	107 10 20	
				71 25 40	70 10 60		5 17 38
SIDI	S. diploscypha			109 10 10			1 10 10
	S. floucescens	Checkermallow		3 20 45	4 0 10	5 25 35	3 15 30
SIGL2	S. glaucescens	Bird checkermallow		109 20 30	101 20 20	102 25 45	
				103 45 35			4 28 32
SIMA2	S. malvaeflora	Foothill checkermallow		109 20 40			1 20 40
	S. nervata	Nelson checkermallow	SW	109 20 30	101 25 30	102 30 30	
				103 35 30			4 23 30
			NW	3 10 20	5 30 30		2 20 25
SIOR	S. oregana	Oregon mallow		3 0 10			1 0 10
	SIEVERSIA	SIEVERSIA	SW	109 0 10			1 0 10
			NW	70 0 10			1 0 10
	S. ciliata	Prairiesmoke sieversia	SW	109 10 20	102 0 20	103 10 0	3 7 13
			NW	3 0 10	4 0 10	107 0 10	3 0 10
SILEN	SILENE	CATCH FLY		70 0 30			1 0 30
SICA4	S. californica	Indian pink		109 0 20			1 0 20
SIGA	S. gallica	Windmill pink		109 10 20			1 10 20
SISYM	SISYMBRIUM	TUMBLE MUSTARD	SW	109 20 30	101 20 20	102 20 20	
				103 20 20			4 20 22
			NW	3 20 20	4 20 20	5 20 20	
				70 0 10			4 15 18
SIAL2	S. altissimum	Tumbling mustard	SW	109 20 30			1 20 30
			NW	3 10 20	107 10 30	6 10 10	
				7 30 0	71 0 20		5 12 16
	S. incisum	Tansy mustard	SW	109 10 20			1 10 20
			NW	3 10 20			1 10 20
	S. longipedicellatum			3 10 20			1 10 20
	S. nasturtium-aquaticum	Water cress	SW	109 40 50	101 45 45	102 35 30	
				103 30 20			4 38 36
			NW	3 45 30	4 45 30	5 35 20	3 42 27

PROPER USE FACTORS FORBS (cont.)

SIOF	S. officinale	Tumble mustard		3 10 20			1 10 20
SISYR	SISYRINCHIUM	BLUE-EYED GRASS	SW	101 25 20	102 0 25	103 25 0	3 17 15
			MW	3 20 30	4 25 25	70 20 60	3 22 45
SIBE	S. bellum	Blue-eyed grass		109 10 20			1 10 20
SISU2	SIUM suave	HEMLOCK WATERPARSNIP		69 30 30			1 30 30
SMILA	SMILACINA	SOLOMON SEAL		107 0 30	71 0 20		2 0 25
SOLID	SOLIDAGO	GOLDENROD	GP	108 10 40			1 10 40
			MW	3 10 20	4 0 45	107 0 10	
				71 0 10	70 10 60		5 4 29
			SW	101 15 15	102 0 35	103 35 0	3 17 17
SOCAS3	S. ciliosa	Goldenrod		3 10 20			1 10 20
	S. elongata	Creek goldenrod	SW	109 20 40	101 20 20	102 0 60	
				103 55 0			4 24 30
			MW	3 10 30	4 20 60	71 0 45	3 10 45
SOMI2	S. missouriensis	Missouri goldenrod	SW	109 10 20	101 20 20	102 0 35	
				103 35 0			4 16 19
			MW	3 10 30	4 10 15	71 0 10	3 7 13
SOOL	S. occidentalis	Western goldenrod		3 10 30			1 10 30
	S. parryi	Parry goldenrod	SW	109 30 40	101 20 20	102 0 35	
				103 35 0			4 21 24
			MW	3 20 35	4 10 15		2 15 25
SOPE	S. petradoria	Rock goldenrod	SW	109 10 20	101 15 15	102 0 35	
				103 35 0			4 15 18
			MW	3 15 35			1 15 35
	S. serotina	November goldenrod		3 10 20			1 10 20
SONCH	SONCHUS	SOW THISTLE	SW	109 10 20			1 10 20
			MW	70 0 10			1 0 10
SOAR2	S. arvensis	Field sow thistle		3 0 20			1 0 20
SOAS	S. asper	Prickly sow thistle		3 0 20			1 0 20
DESO2	SOPHIA	TANSY MUSTARD	SW	109 10 10	101 5 15	102 5 20	
	DESCURAINIA SOPHIA			103 30 10			4 12 14
			MW	3 15 30	4 0 20	5 5 10	
				70 0 10			4 5 18
			GP	108 0 10			1 0 10
SPHAE	SPHAERALCEA	GLOBE MALLOW	SW	109 20 30	101 5 10	102 20 60	
				103 35 35			4 20 34
			MW	3 10 30	4 5 30	5 20 35	
				107 10 30	71 10 20	70 0 10	6 9 34
	S. acerfolia	Globe mallow		3 20 40	5 20 20		2 20 30
SPCA4	S. caespitosa	Globe mallow	SW	109 20 30	101 15 15	102 30 45	
				103 45 40			4 28 32
			MW	3 15 45	4 15 45	5 30 45	3 20 45
SPGR2	S. grossalariaofolia	Globe mallow	SW	109 40 40	101 20 35	102 65 50	
				103 55 70			4 45 49
			MW	3 30 60	4 20 50	5 65 70	3 38 60
SPMV2	S. munroana	Globe mallow	SW	109 50 50			1 50 50
			MW	3 20 40			1 20 40
	S. rivularis	Wild hollyhock		3 0 10			1 0 10
	SPHENOSCIADIUM capitella	RANGE WOOLY HEAD PARSNIP		3 40 60			1 40 60
STACH	STACHYS	HEDGENETTLE		109 0 10			1 0 10
	S. ciliata	Oregon betony		71 0 30			1 0 30
STPA	S. palustris	Marsh betony		3 0 30			1 0 30
STELL	STELLARIA	STARWORT		70 0 10			1 0 10

PROPER USE FACTORS — FORBS (cont.)

STJA2	S. jamesiana	Tuber starwort	SW	109 20 20			1 20 20
			NW	3 15 60	4 20 60	107 20 40	3 18 53
STME2	S. media	Common chickweed	SW	109 20 40			1 20 40
			NW	3 10 10	107 0 10		2 5 10
STREP2	STREPTANTHUS	TWIST FLOWER		109 20 30			1 20 30
STREP	STREPTOPUS	TWISTED STALK		71 0 20			1 0 20
SUAED	SUAEDA	SEA BLITE		101 5 10	102 20 10	103 20 40	3 15 20
	S. depressa var. erecta	Pursh seepweed		3 10 20			1 10 20
SWERT	SWERTIA	FRAZERA		109 10 20			1 10 20
SYNTH2	SYNTHYRIS	RED KITTENTAILS		70 0 70			1 0 70
TARAX	TARAXACUM	DANDELION	SW	109 50 70			1 50 70
			GP	108 50 70			1 50 70
	T. officincale	Dandelion		3 50 70	107 60 70	6 50 50	
				7 50 50	71 25 50		5 47 58
	TARAXIA subaccaulis	TAREXIA		101 20 20	103 0 45	103 45 0	3 22 22
THALI2	THALICTRUM	MEADOW RUE	SW	109 10 20	101 15 20	102 0 20	
				103 15 0			4 10 15
			NW	3 0 15	4 0 10	107 10 30	
				70 0 10			4 0 16
THAL	T. alpinum	Alpine meadowrue		3 0 10			1 0 10
THFE	T. fendleri	Fendler meadowrue	SW	102 0 20	103 20 0		2 10 10
			NW	3 0 20	4 0 20	71 0 10	3 0 17
THOC	T. occidentale	Western meadowrue		3 0 10	71 0 10		2 0 10
THELY	THELYPODIUM	THELYPODIUM	SW	109 10 10	101 0 10	102 0 10	
				103 10 0			4 5 8
			NW	3 0 10	4 0 10	71 0 10	3 0 10
	T. lacinatum	Thelypody		3 0 10			1 0 10
THERM	THERMOPSIS	GOLDENPEA		109 30 30	101 5 5	102 0 10	
				103 15 0			4 11 11
THMA2	T. macrophylla	Bigleaf thermopsis		109 20 20			1 20 20
THMO3	T. montana	Mountain thermopsis	SW	109 10 10	101 5 5	102 0 10	
				103 15 0			4 8 6
			NW	3 5 10	102 0 10		2 3 10
THLAS	THLASPI arvense	PENNYCRESS		3 0 10			1 0 10
	T. glaucum	Mountain pennycress		3 0 10	71 0 10		2 0 10
THYSA	THYSANOCARPUS	FRINGE POD		109 10 20			1 10 20
	TITHYMALUS			102 0 5			1 0 5
TOWNS	TOWNSENDIA	TOWNSENDIA	SW	109 20 20	101 10 20	102 0 15	
				103 25 0			4 14 11
			NW	3 20 25	4 10 15	70 0 60	3 10 33
TOFL2	T. florifer		SW	101 10 20	102 0 15	103 25 0	3 12 12
			NW	3 0 10	4 10 15		2 5 12
TOPA2	T. parryi	Parry townsendia		3 0 10			1 0 10
	T. watsonii			3 0 10			1 0 10
	TRAGOPOGON	SALSIFY		70 0 50			1 0 50
	T. porrifolius	Vegetable-oyster salsify	SW	109 20 40			1 20 40
			NW	3 20 40	107 20 40	71 5 30	3 15 37
	T. pratensis	Meadow salsify		3 20 40	107 20 40		2 20 40
TRCA	TRAUTVETTERIA grandis	OREGON FALSE BUGBANE		71 0 50			1 0 50
TRIFO	TRIFOLIUM	CLOVER	SW	109 50 60	101 80 80	102 80 80	
				103 80 80			4 72 75
			GP	108 80 80			1 80 80
			NW	3 70 70	4 80 80	5 80 80	

PROPER USE FACTORS FORBS (cont.)

TRIFO	Trifolium	Clover	NW	107 60 60	5 50 50	7 50 50	
				71 35 50	70 80 80		3 66 68
TRAG	T. agrarium	Hop clover		3 30 50			1 30 50
TRDO	T. douglasii	Douglas clover		3 30 50			1 30 50
TRER2	T. eriocephalum	Woolyhead clover		71 10 10			1 10 10
TRFR2	T. fragiferum	Strawberry clover		107 80 80			1 80 80
TRHY	T. hybridum	Alsike clover		3 80 80	71 50 50		2 65 65
TRLA8	T. latifolium	Broadleaf clover		3 80 80	107 80 80		2 80 80
TRLO	T. longipes	Longstalk clover		71 50 50			1 50 50
TRMA3	T. macrocephalum	Bigleaf clover		3 80 80	107 80 80	71 10 10	3 57 57
TRPL2	TRIFOLIUM plumosum	PUSSY CLOVER		3 30 50			1 30 50
TRPR2	T. pratense	Red clover		3 80 80	107 80 80		2 80 80
TRRE3	T. repens	Ladino clover	SW	109 80 80			1 80 80
			NW	3 80 80	107 40 40	71 50 50	3 57 57
	T. rydbergii	Rydberg clover		3 80 80			1 80 80
TRILL	TRILLIUM	WAKE ROBIN		107 0 30	70 10 80		2 5 55
TROLL	TROLLIUS	GLOBE FLOWER		70 10 80			1 10 80
	T. albiflorus	Globe flower		3 0 10			1 0 10
	UMBELLIFERAE	PARSLEY FAMILY		109 10 10			1 10 10
	UROPAPPUS linearifolius			109 10 10			1 10 10
	U. urens			109 10 0			1 10 0
URTIC	URTICA	NETTLE	SW	109 10 20	101 15 15	102 20 15	
				103 30 20			4 19 18
			NW	3 10 20	4 5 10	5 20 20	
				107 20 10	5 20 20	7 10 10	6 13 15
URLY	U. lyallii	Stinging nettle		71 0 20			1 0 20
VACCI	VACCARIA	COW-HERB		70 10 30			1 10 30
	V. vulgaris	Cowcockle		3 10 20			1 10 20
	VAGNERA	FALSE SOLOMONSEAL	SW	102 0 25			1 0 25
			NW	70 10 20			1 10 20
	V. amplexicaulis	False solomonseal		102 0 25			1 0 25
	V. liliacea	False solomonseal		102 0 25	103 15 0		2 8 12
VALER	VALERIANA	VALERIAN	SW	109 10 20	101 10 10	102 0 50	
				103 40 0			4 15 18
			NW	3 10 30	4 0 40	107 10 40	
				71 20 50	70 30 60		5 14 36
	V. edulis	Edible valeriana	SW	101 10 10	102 0 35	103 30 0	3 13 15
			NW	3 10 30	4 10 35		2 10 32
VAOC2	V. occidentalis	Valerian	SW	109 20 30	101 15 10	102 0 60	
				103 30 0			4 16 25
			NW	3 10 30	4 15 60		2 12 45
VASI	V. sitchensis	Sitka valeriana		3 10 30			1 10 30
VERAT	VERATRUM	FALSE HELLEBORE		109 30 50			1 30 50
VECA2	V. californicum	California false hellebore	SW	109 20 30	101 25 20	102 0 30	
				103 25 0			4 18 20
			NW	3 20 40	4 15 40	107 60 60	
				71 10 30			4 26 42
VEVI	V. viride	American western false hellebore		3 10 20	107 60 60		2 35 40
VERBA	VERBASCUM	MULLEIN		70 0 10			1 0 10
VETH	V. thapsus	Common mullien		109 0 10			1 0 10
VERBE	VERBENA	VERVAIN		109 10 10			1 10 10
VERON	VERONICA	SPEEDWELL		107 10 20	71 0 20		2 5 20
VEAM2	V. americana	American speedwell	SW	109 60 60	101 15 10	102 0 25	

PROPER USE FACTORS FORBS (cont.)

VEAM2	V. americana	American speedwell	SW	103 20 0			1 21 14
			NW	3 10 20	4 10 20	71 0 20	3 7 20
VEPE2	V. peregrina	Neckweed		109 10 10			1 10 10
VICIA	VICIA	VETCH	SW	109 50 60	101 60 60	102 0 65	
				103 60 0			1 12 46
			GP	108 50 70			1 50 70
			NW	3 60 60	4 10 60	107 50 60	
				6 50 40	7 20 10	71 50 60	
				70 50 50			7 41 53
VIAM	V. americana	American vetch	SW	109 70 80	101 60 60	102 0 65	
				103 60 0			1 48 51
			GP	09 40 40			1 40 40
			NW	3 60 60	4 40 50	107 50 60	
				71 50 60			4 50 56
VIVI	V. villosa	Hairy vetch		3 60 60	107 50 60		2 55 60
VIMU	VIGUIERA multiflora	MANY FLOWERED SUN FLOWER	SW	109 20 30	101 30 30	102 0 40	
				103 40 0			4 22 23
			NW	3 10 30	4 10 30	107 10 30	3 10 30
VIOLA	VIOLA	VIOLET	SW	109 10 30	101 10 10	102 0 15	
				103 15 0			4 9 21
			GP	105 10 30			1 10 30
			NW	3 0 10	4 0 10	107 0 20	
				6 10 0	7 20 10	71 0 10	
				70 0 80			7 4 20
	V. beckwithii	Beckwith violet	SW	101 10 10	102 0 15	103 15 0	3 8 8
			NW	3 0 10	4 10 15		2 5 12
	V. lingaefolia	Nuttall violet		70 0 30			1 0 30
VIPU4	V. purpurea	Goosefoot violet	SW	101 10 10	102 0 20	103 15 0	3 8 10
			NW	3 10 20	4 10 20		2 10 20
WIRE	WISLIZENIA refracta	JACKASS CLOVER		109 20 30			1 20 30
WYETH	WYETHIA	MULE'S EAR	SW	109 20 30			1 20 30
			GP	108 0 20			1 0 20
	W. amplexicaulis	Mountain mules ear	SW	109 30 30	101 60 40	102 40 15	
				103 35 30			4 31 23
			NW	3 10 30	4 10 30	5 10 30	
				107 10 20	6 10 0	7 30 10	
				71 20 20			7 21 20
WYAN	W. angustifolia	Narrowleaf wyethia		109 20 30			1 20 30
WYHE2	W. helianthoides	Whitehead mules ear	SW	109 40 60	101 35 35	102 0 35	
				103 35 0			4 28 30
			NW	3 10 20	107 10 20	6 10 0	
				7 20 10	71 10 20		5 12 14
WYMO	W. mollis	Wooly mules ear	SW	109 10 30			1 10 30
			NW	71 10 10			1 10 10
WYOV	W. ovata			109 30 40			1 30 40
	ZYGADENUS	DEATH CAMAS	SW	109 P P	103 10 0		2 10 0
			NW	3 P P	107 P P	71 P P	3 P P
	Z. elegans	Mountain death camas		3 P P	107 P P		2 P P
	Z. gramineus	Grassy death camas		3 P P	107 P P		2 P P
	Z. paniculatus	Foothill death camas		3 P P	107 P P		2 P P
	Z. venenosus	Meadow death camas		3 P P	107 P P		2 P P

SHRUBS AND TREES
PROPER USE FACTORS

ACGR	ACACIA greggii	CATCLAW		109	10	10	101	0	10	103	10	0	3	7	7
ACSH	ACAMPTOPAPPUS shockleyi	SHOCKLEY GOLDENHEAD		109	10	10							1	10	10
ACER+	ACER	MAPLE	SW	109	10	10	101	5	5	102	0	15			
				103	25	0							4	10	8
			NW	3	10	10	4	10	10	5	10	10			
				107	20	50							4	12	20
ACCI	A. circinatum	Vine maple		6	20	30	7	10	10	71	10	20	3	13	20
ACGL	A. glabrum	Rocky Mt. maple		3	10	20	4	10	20	107	20	50			
				6	10	10	7	20	20	71	10	20			
				70	0	10							7	11	21
ACGR3	A. grandidentatum	Bigtooth maple		3	10	10	4	10	10				2	10	10
ACMA3	A. macrophyllum	Bigleaf maple		109	10	20							1	10	20
ACNE2	A. negundo	Box elder	SW	109	10	20							1	10	20
			NW	3	10	10	4	10	10				2	10	10
ADFA	ADENOSTEMA fasciculatum	CHAMISE		109	10	10							1	10	10
AECA	AESCULUS californica	CALIFORNIA BUCKEYE		109	20	20							1	20	20
ALOC2	ALLENROLFEA occidentalis	BUSH PICKLEWEED		109	10	10							1	10	10
ALNUS	ALNUS	ALDER	SW	109	20	30							1	20	30
			NW	71	0	10							1	10	10
ALRH2	A. rhombifolia	Alder		109	20	30							1	20	30
ALSI3	A. sinuata	Sitka alder		3	10	20	4	10	20	70	0	10	3	7	17
ALTE3	A. tenuifolia	Mountain alder	SW	102	0	10							1	0	10
			NW	107	10	50							1	10	50
AMELA	AMELANCHIER	SERVICE BERRY	SW	109	30	50	101	25	25	102	35	45			
				103	30	30							4	30	35
			GP	108	60	60							1	60	60
			NW	3	40	60	4	30	65	5	35	30			
				107	30	60	25	40	40	26	40	40	6	36	49
AMAL2	A. alnifolia	Western service berry	SW	109	40	50	101	25	35	102	0	35			
				103	25	20							4	22	32
			NW	3	40	60	4	25	35	5	0	20			
				107	30	60	71	40	40	70	50	60	6	32	49
			GP	69	20	40							1	20	40
AMFL	A. florida	Pacific service berry		3	40	60	107	30	60	6	20	10			
				7	30	20							4	30	35
	APLOPAPPUS heterophyllus	JERKY WEED		102	0	P	103	P	0				2	P	P
APAN2	APOCYNUM androsaemifolium	SPREADING DOGBANE		70	10	10							1	10	10
ARTEM	ARTEMISIA	SAGEBRUSH		109	10	40	101	15	15	102	20	15			
				103	40	40							4	21	28
ARAB3	A. absinthium	Wormwood		3	0	5							1	0	5
ARAR8	A. arbuscula	Blacksage	SW	109	10	20							1	10	20
			NW	3	0	10							1	0	10
ARBI3	A. bigelovii	Flat sagebrush		109	20	40							1	20	40
ARCA11	A. californica	California sagebrush		109	10	10							1	10	10
ARCA13	A. cana	Silver sagebrush	SW	109	10	10	101	10	10	102	10	20			
				103	20	20							4	12	15
			GP	108	20	30	69	10	50				2	15	40
			NW	3	0	10	4	10	20	5	10	20			
				7	10	0	71	0	5	70	0	5	6	5	10
ARDR4	A. dracunculoides	Redstem sage	SW	109	10	30	101	0	10	102	35	15			
				103	15	50							4	22	26
			GP	108	0	20							1	0	20

PROPER USE FACTORS SHRUBS AND TREES (cont.)

ARDR4	A. dracunculoides	Redstem sage	IW	3	10	30							1	10	30
ARFI2	A. filifolia	Sand sage	SW	109	10	20	101	0	5	102	10	5			
				103	15	15							4	9	11
			IW	3	10	15	4	0	10	5	10	15	3	7	13
	A. forwoodii	Green sage	GP	108	0	20							1	0	20
			IW	70	10	20							1	10	20
ARFR4	A. frigida	Fringed sagewort	SW	109	20	40							1	20	40
			GP	108	10	30							1	10	30
			IW	3	20	30	71	0	20	21	20	30			
				22	20	20	23	20	30	70	10	20	6	15	25
	A. gnaphalodes	Cudweed sagewort	SW	101	20	15	102	20	30	103	45	50	3	28	32
			IW	3	10	30	70	10	20				2	10	25
	A. heterophylla			3	0	5							1	0	5
ARLU	A. ludoviciana	Cudweed sagewort		3	0	10							1	0	10
ARLO7	A. longifolia	Longleaf sagebrush		69	10	50							1	10	50
	A. nova	Low sage	SW	109	10	50	101	0	10	102	20	20			
				103	70	75							4	25	39
			IW	3	0	20	4	0	10	5	20	50			
				21	10	20	22	0	10	23	20	30			
				6	10	0	7	30	5				8	11	18
	A. paniculata			3	0	5							1	0	5
ARPE6	A. pedatifida	Birdsfoot sage		108	30	60							1	30	60
ARCA12	A. pycnocephala	Sagebrush		109	10	10							1	10	10
ARSP5	A. spinescens	Bud-sage	SW	109	40	60	101	0	35	102	25	15			
				103	75	75							4	35	46
			IW	3	0	20	4	0	15	5	25	75			
				6	10	0	7	20	0	21	10	20			
				22	10	50							7	11	26
ARTR2	A. tridentata	Big sagebrush	SW	109	10	20	101	10	10	102	10	10			
				103	15	25							4	11	16
			GP	108	10	20							1	10	20
			IW	3	0	10	4	0	10	5	10	15			
				7	5	0	71	5	10	70	0	5	6	3	8
ARTR4	ARTEMISIA tripartida	THREE TIPPED SAGE-BURSH	SW	109	10	10	101	10	10	102	10	10			
				103	15	15							4	11	11
			IW	3	10	10	4	0	10	5	0	10			
				7	5	0	71	5	5				5	4	7
ARVU	A. vulgaris	Mugwort	SW	109	10	20							1	10	20
			IW	3	0	5							1	0	5
	A. wrightii	Wright sage		109	20	40							1	20	40
ARTRIP	ATRIPLEX	SALTBUSH	SW	109	20	40	101	10	20	102	10	15			
				103	45	50							4	29	32
			IW	3	10	40	4	10	15	5	40	50	3	20	35
ARTRIP	ATRIPLEX annual	CRACH	SW	101	20	20	102	20	20	103	20	20	3	20	20
			IW	3	10	20							1	10	20
ATCA2	A. canescens	Fourwing saltbush	SW	109	40	40	101	0	20	102	50	0			
				103	40	30							4	35	22
			GP	108	20	50							1	20	50
			IW	3	10	40	5	60	30	6	10	0			
				7	40	0	70	0	10				5	24	15
ATCO	A. confertifolia	Shadscale	SW	109	30	40	101	0	10	102	10	0			
				103	30	45							4	18	24
			IW	3-10	40		5	10	15	6	10	0			
				7	30	0	21	10	10	23	10	15	6	13	28

PROPER USE FACTORS SHRUBS AND TREES (cont.)

ATCO4	A. corrugata	Mat sagebrush	SW	101	15	35	102	10	25	103	50	65	3	[illegible]	[illegible]
			NM	3	10	40	4	15	25	5	40	65	3	22	43
ATNUC	A. cuneata	Saltbush		109	10	30							1	10	30
	A. greggii	Prostrate saltbush		109	10	10							1	10	10
	A. hastata	Spearleaf fat-hen saltbush		3	10	20							1	10	20
	A. hortensis	Garden orach		3	10	20							1	10	20
ATLE	A. lentiformis	Quial bush		109	30	40							1	30	40
ATNU2	A. nuttallii	Nuttall saltbush	SW	109	30	40	101	15	25	102	45	25			
				103	50	65							4	35	49
			GP	108	40	70							1	40	70
			NM	3	10	40	4	15	25	5	40	65			
				21	10	40	22	40	40	23	40	65			
				6	20	20	7	40	20				8	27	39
ATPA4	A. patula	Fat-hen saltbush		3	10	20							1	10	20
ATPO	A. polycarpa	Allscale		109	10	10							1	10	10
ATRO	A. rosea	Australian saltbush		3	10	20							1	10	20
	A. sabulosa	Saltbush		109	20	30							1	20	30
BACCH	BACCHARIS	COYOTE BRUSH		109	0	10							1	0	10
BETUL	BETULA	BIRCH		71	5	10							1	5	10
BEOC2	B. fontinalis	Red birch		3	10	10	4	10	10	71	0	10	3	7	10
BEGL	B. glandulosa	Resin birch	SW	102	0	15							1	0	15
			NM	3	10	10	4	0	15				2	5	12
BEPA	B. papyrifera	Paper birch		3	10	10							1	10	10
CALLI	CALLIANDRA	FALSE MESQUITE		101	0	70	103	60	0				2	30	35
CEANO	CEANOTHUS	CEANOTHUS		109	20	20							1	20	20
CECO	C. cordulatus	Mountain whitehorn		109	10	20							1	10	20
CECU	C. cuneatus	Buck brush		109	10	20							1	10	20
	C. divaricatus			109	20	20							1	20	20
CEFE	C. fendleri	Fendler ceanothus	SW	109	20	20	101	5	15	102	0	10			
				103	20	0							4	11	11
			NM	3	10	10	4	10	10				2	10	10
CEGR	C. greggii	Desert ceanothus		109	20	30							1	20	30
CEIN3	C. integerrimus	Deer brush	SW	109	30	70							1	30	70
			NM	25	40	40	26	40	40	71	40	40	3	40	40
	C. macrocarpus	Bigpod ceanothus		109	30	40							1	30	40
CEMA2	C. martini	Ceanothus	SW	109	10	20	101	10	20	102	0	30			
				103	20	0							4	10	18
			NM	3	10	10	4	10	10	5	10	10	3	10	10
CESA	C. sanguineus	Redstem ceanothus		3	40	50	107	40	50	14	30	40			
				25	40	40	26	40	40	71	30	40			
				70	40	50							7	37	54
CESO2	C. sorediatus	Jim brush		109	30	40							1	30	40
CETH	C. thyrsiflorus	Blue blossom		109	10	20							1	10	20
CEVE	C. velutinus	Snowbrush	SW	102	0	15							1	0	15
			NM	71	0	10							1	0	10
CECI2	CERCIS	RED BUD		109	20	50							1	20	50
	C. arizonica	Red bud		109	0	10							1	0	10
CEOC3	C. occidentalis	Western red bud		109	20	30							1	20	30
CERCO	CERCOCARPUS	MOUNTAIN MAHOGANY		109	50	50							1	50	50
	C. arizonica	Mt. mahogany		109	10	20							1	10	20
CEMO2	C. betuloides	Western Mt. mahogany		109	50	60							1	50	60
CEMOP	C. brevifolius	Mt. mahogany		109	70	70							1	70	70
CELEI2	C. intricatus	Littleleaf mahogany		109	10	20							1	10	20

PROPER USE FACTORS SHRUBS AND TREES (cont.)

CELE	C. lecifolius	Curlleaf Mt. mahogany	SW	109 10 30	101 0 5	102 0 10	
				103 15 50			4 6 24
			NW	3 20 15	4 20 10	5 30 25	
				71 10 20	6 10 10	7 20 20	
				50 40 60	51 20 30	52 40 50	
				53 20 30	54 30 50	55 10 20	
				56 25 40	57 10 20	53 15 25	
				58 0 10	59 40 60	60 20 30	
				61 40 60	62 20 30	63 30 50	
				64 10 20	65 25 40	66 10 20	
				67 15 25	68 0 10	81 40 60	
				82 20 30	83 40 60	84 20 30	
				85 30 50	86 10 20	87 25 40	
				88 10 20	89 15 25	90 0 10	
				91 40 60	92 20 30	93 40 60	
				94 20 30	95 30 50	96 10 20	
				97 25 40	98 10 20	99 15 25	
				100 0 10			
CEMO2	C. montanus	Mt. mahogany	SW	109 60 70			1 60 70
			GP	108 30 50			1 30 50
			NW	70 40 80			1 40 80
CHRY9	CHRYSOTHAMNUS	RABBITBRUSH	SW	109 10 10	101 5 5	102 15 10	
				103 25 30			4 14 11
			NW	3 10 10	6 10 0	7 10 0	3 10 3
	C. lanceolatus	Lanceleaf rabbit brush	SW	109 20 30			1 20 30
			GP	108 10 20			1 10 20
			NW	3 10 20	4 10 10	5 10 15	
				7 20 0			4 12 11
CHNA2	C. nauseosus	Rubber rabbitbrush	SW	109 0 10	101 0 5	102 5 5	
				103 5 10			4 2 8
			GP	108 0 10			1 0 10
			NW	70 0 10	7 10 0		2 5 5
CHPA12	C. paniculatus	Sticky rabbitbrush	SW	109 10 20	101 5 5	102 10 10	
				103 15 15			4 10 12
			NW	5 10 15			1 10 15
	C. paberulus	Rabbit brush	SW	109 0 10	101 5 5	102 10 10	
				103 20 20			4 9 11
			NW	3 10 10	4 0 10	5 10 20	3 7 13
	C. stenophyllus	Rabbitbrush	SW	101 5 5	102 15 10	103 15 30	3 12 15
			NW	3 10 20	5 15 30		2 12 25
CHVI8	C. viscidiflorus	Rabbitbrush	SW	109 10 20	101 10 15	102 30 10	
				103 35 40			4 21 25
			NW	3 10 20	5 30 40		2 20 30
CERCI	CERCIDIUM	PALOVERDE		101 0 10			1 0 10
CLEMA	CLEMATIS	CLEMATIS		109 10 10			1 10 10
	C. columbiana	Clematis		70 0 20			1 0 20
	C. douglasii	Headache weed		70 0 40			1 0 40
CLLI2	C. ligusticifolia	Western clematis	SW	109 10 10	101 10 10	102 0 20	
				103 15 0			4 9 20
			NW	3 10 10	4 10 10		2 10 10
CORA	COLEOGYNE ramosissima	BLACK BUSH		109 10 20	101 0 20	103 30 0	3 13 13
CORNU	CORNUS	DOGWOOD		109 10 20			1 10 20
COCA13	C. canadensis	Bunchberry		70 0 10			1 0 10
CONU4	C. nuttallii	Pacific dogwood		70 0 10			1 0 10

PROPER USE FACTORS SHRUBS AND TREES (cont.)

COST4	C. stolenifera	Redosier dogwood	SW	102 0 10	103 5 0		2 2 5
			NW	3 0 10	4 10 10	107 30 70	
				71 0 10			4 10 25
	CORYLUS rostrata	CALIFORNIA HAZELNUT		109 10 10			1 10 10
COWAN	COWANIA	CLIFFROSE	SW	101 50 55	102 45 60	103 60 55	3 52 57
			NW	3 55 60	4 50 60	5 45 55	
				6 40 50	7 50 50		5 48 55
COME5	C. mexicana	Cliffrose		109 50 60			1 50 60
CRDO2	C. douglasii	Western blackhaw	SW	109 10 10			1 10 10
			NW	3 0 10	107 10 20	71 0 5	
				70 40 80			4 12 29
CRRI	C. rivularis	Western blackhaw	SW	109 0 10	102 0 10	103 10 0	3 3 7
			NW	3 10 10			1 10 10
CUMA2	CUPRESSUS macrocarpa	MONTEREY CYPRESS		109 10 10			1 10 10
DAFO	DALEA formosa			109 10 30			1 10 30
DAFR	D. fremontii	Fremont dalea		109 10 10			1 10 10
DAPO2	D. polyadenia	Nevada dalea		109 10 20			1 10 20
DASP	D. spinosa	Smoke tree		109 10 30			1 10 30
	D. fruticosa	Shrubby cinquefoil	SW	101 20 15	102 0 10	103 15 40	3 22 32
			GP	108 10 30			1 10 30
			NW	3 0 20	4 20 40	5 0 40	
				70 10 70			4 8 42
DERI	DENDROMECON rigida	BUSH POPPY		109 10 10			1 10 10
ELCO	ELAEAGNUS commutata	SILVERBERRY	GP	69 10 20			1 10 20
			NW	70 20 80			1 20 80
	EMPLACTOCLADUS fasiculatus	DESERT ALMOND	SW	101 20 20	102 0 15	103 10 0	3 10 12
			NW	3 20 10			1 20 10
ENCEL	ENCELIA	BRITTLEBRUSH		109 10 20			1 10 20
ENFA	E. farinosa	Desert encelia		109 10 20			1 10 20
EPNE	EPHEDRA nevadensis	NEVADA EPHEDRA	SW	109 30 40	101 10 15	102 30 10	
				103 30 55			4 25 30
			NW	3 15 30	4 10 10	5 30 55	3 18 32
EPTO	E. torreyana	Torrey ephedra		109 20 30			1 20 30
	E. trifurca	Three forked ephedra		109 20 30			1 20 30
EPVI	E. viridis	Green ephedra	SW	109 20 20	103 10 20		2 15 20
			NW	3 0 10	5 0 20		2 0 15
ERIOG	ERIOGONUM	WILD BUCKWHEAT		109 10 20			1 10 20
	E. fasciculatus	California wild buckwheat		109 10 20			1 10 20
ERHE2	E. heracleoides	Wyeth eriogonum		101 15 15	102 15 30	103 35 40	3 22 28
ERWR	E. wrightii	Wright buckwheat		109 10 30			1 10 30
ERIOP2	ERIOPHYLLUM	ERIOPHYLLUM		109 20 20			1 20 20
EULA5	EUROTIA lanta	WINTER FAT	SW	109 50 60	101 50 65	102 70 50	
				103 65 55			4 59 60
			GP	108 30 60	69 55 55		2 42 58
			NW	3 30 50	4 50 50	5 70 65	
				21 30 50	22 50 50	23 60 50	
				6 20 30	7 40 40	70 10 80	9 40 52
FAPA	FALLUGIA paradoza	APACHE PLUME		109 40 50			1 40 50
	FENDLERA falcata	FENDLER BUSH		109 40 50			1 40 50
FONE	FORESTIERA neomexicana	ADELIA		109 0 10			1 0 10
FRANS	FRANSERIA	BURSAGE		109 20 30			1 20 30
FRDU	F. damosa	White bursage		109 20 30			1 20 30
FRAXI	FRAXINUS	ASH	SW	109 10 10			1 10 10

PROPER USE FACTORS SHRUBS AND TREES (cont.)

FRAXI	FRAXINUS	Ash	GP	108 30 60	5[illegible] 5[illegible] 55		2 42 5[illegible]
	F. lanceolata	Green ash		70 10 30			1 10 30
FRCA4	FREMONTIA californica	FLANNEL BUSH		109 40 50	- - -		1 40 50
GRAYI	GRAYIA	HOP-SAGE		101 0 15	102 25 15	103 25 45	3 17 25
	G. brandegei	Hop-sage	SW	101 0 15	102 25 13	103 40 45	3 22 25
			IW	3 15 40	4 0 15	5 35 45	3 17 33
GRSP	G. spinosa	Hop-sage	SW	109 40 50	101 0 10	102 25 15	
				103 40 45			4 26 38
			IW	3 10 10	4 0 15	5 25 45	
				21 10 10	23 20 40	6 5 0	
				7 10 10			7 11 18
	GROSSULARIA	GOOSEBERRIES	GP	108 10 20			1 10 20
			SW	109 20 40	101 10 5	102 0 20	
				103 20 0			4 12 16
	G. inermis	White stem gooseberry	SW	101 15 25	102 0 35	103 40 0	3 18 20
			IW	70 10 20			1 10 20
GUTIE	GUTIERREZIA	SNAKEWEED		103 5 10			1 5 10
GUSA2	G. sarothrae	Broom snake weed	SW	101 0 5	103 5 10		2 2 8
			IW	3 0 10	7 10 0	70 0 10	3 3 7
HODI	HOLODISCUS discolor	CREAM BUSH	SW	109 10 20			1 10 20
			IW	3 10 10	107 10 30	6 10 10	
				7 10 10	71 10 10		5 10 14
HYSA	HYMENOCLEA salsola	WHITE BURROBRUSH		109 10 10			1 10 10
HAPE	ISOCOMA wrightii	RAYLESS GOLDENROD		109 P P			1 P P
JUNIP	JUNIPERUS	JUNIPER		101 0 5	102 10 0	103 5 15	3 5 7
JUCA7	J. californica	California juniper		109 0 10			1 0 10
	J. utahensis	Utah juniper	SW	109 5 5	101 0 5	102 10 0	
				103 5 15			4 5 6
			IW	5 10 15			1 10 15
KAPO	KALMIA polifolia	ALPINE LAUREL		109 P P			1 P P
KOCHI	KOCHIA	MOLLY	SW	109 20 20	101 5 15	102 25 10	
				103 25 40			4 20 21
			GP	108 0 10			1 0 10
KOAM	K. americana	Green molly		109 0 40			1 0 40
	K. vestita	Gray molly		101 5 15	102 25 10	103 25 40	3 18 22
KRPA	KRAMERIA parvifolia	RANGE RATANY		109 20 30			1 20 30
LEGL	LEDUM glandulosum	WESTERN LABRADORE TEA		70 0 20			1 0 20
	LEPARGYREA canadensis	RUSSET BUFFALOBERRY	SW	102 0 5			1 0 5
			IW	70 10 30			1 10 30
LINNA	LINNAEA borealis	TWIN FLOWER	SW	109 10 20			1 10 20
			IW	107 0 20			1 0 20
LONIC	LONICERA	HONEYSUCKLE		109 20 30			1 20 30
LOCI3	L. ciliosa	Climbing honeysuckle		107 0 10			1 0 10
LOIN5	L. involucrata	Twinberry	SW	109 20 30	102 0 30	103 40 0	3 20 20
			IW	3 0 25	4 0 15	107 0 10	3 0 17
LOUT2	L. utahensis	Utah honeysuckle		4 0 20	107 20 70		2 10 45
LOTUS	LOTUS	BIRDSFOOT TREFOIL		109 30 40			1 30 40
LOSC2	L. scoparius	Deerwood		109 20 40			1 20 40
LUPIN	LUPINUS	LUPINE		109 10 10			1 10 10
LUAL4	L. albifrons	Silver lupine		109 20 20			1 20 20
LUAR	L. arboreus	Tree lupine		109 20 20			1 20 20
LUCH	L. chamissonis	Dune lupine		109 10 10			1 10 10
LYAN	LYCIUM andersonii	ANDERSON DESERT THORN		109 10 10			1 10 10

PROPER USE FACTORS SHRUBS AND TREES (cont.)

LYGOD	LYGODESMIA	SKELETON PLANT		109 10 10	101 10 10	102 10 10	
				103 10 10			4 10 10
	L. spinosa	Thorn skeleton plant	SW	101 10 10	102 10 10	103 10 10	3 10 10
			NW	3 10 10	4 10 10	5 10 10	3 10 10
	MENODORA scabra	SMOOTH MENODORA		109 40 40			1 40 40
	M. spinescens	Spiny menodora		109 10 10			1 10 10
MEFE	MENZIESIA ferruginea	FOOLS HUCKLEBERRY		107 0 30	71 10 20		2 5 25
MYCA	MYRICA californica	PACIFIC WAX-MYRTLE		109 10 10			1 10 10
NIGL	NICOTIANA glauca	TREE TOBACCO		109 P P			1 P P
	NOLINA microcarpa	BEAR GRASS		109 10 10			1 10 10
	OPULASTER malvaceus	NINE BARK	SW	109 10 10	101 5 5	102 0 15	
				103 15 20			4 8 12
			NW	70 0 10			1 0 10
PAMY	PACHISTIMA myrsinites	OREGON BOXWOOD	SW	109 10 10			1 10 10
			NW	3 0 10	107 0 40	71 0 5	3 0 13
	PALOVERDE	PALOVERDE		101 0 10			1 0 10
PEFR3	PENSTEMON fruticosus	BRUSH PENSTEMON		3 0 10	4 0 10	107 0 10	
				70 0 20			4 0 12
PERA4	PERAPHYLLUM ramosissimum	SQUAW APPLE		109 30 30			1 30 30
PHLE4	PHILADELPHUS lewisii	MOCK ORANGE	SW	101 0 10	102 0 5	103 10 0	3 3 5
			NW	3 10 10	4 0 10	107 30 50	
				71 10 10	70 30 60		5 16 28
PHMA5	PHYSOCARPUS malvaceus	MALLOW NINEBARK		3 10 20	4 0 20	5 0 20	
				107 30 40	71 5 20		5 9 22
POPUL	POPULUS	COTTONWOOD		109 30 40			1 30 40
POAN3	P. angustifolia	Narrowleaf cottonwood	SW	109 20 30			1 20 30
			NW	3 10 10	6 10 10	7 10 10	
				70 10 50			4 10 20
POBA2	P. balsamifera	Southern poplar		69 10 10			1 10 10
	P. candicans	Balm of Gilead poplar		69 10 10			1 10 10
	P. hastata	Aspen		3 10 10			1 10 10
POSA8	P. sargentii	Plains poplar		69 10 10			1 10 10
POTR5	P. tremuloides	Quaking aspen	SW	109 30 40	101 15 15	102 0 30	
				103 30 0			4 19 21
			GP	108 20 50	69 10 10		2 15 30
			NW	3 20 40	4 15 30	107 40 60	
				6 20 20	7 40 30	71 20 40	
				70 10 50			7 19 40
POTR6	P. trichocarpa	Black cottonwood	GP	69 10 10			1 10 10
			NW	71 10 10			1 10 10
POFR4	POTENTILLA fruticosa	Shrubby cinquefoil	SW	109 20 40			1 20 40
			GP	108 10 10			1 10 10
			NW	71 0 20			1 0 20
PROSO	PROSOPIS	MESQUITE		109 20 10	101 0 20	103 20 0	3 13 10
	P. chilensis	Honey mesquite		109 20 10			1 20 10
	P. glandulosa	Honey mesquite		101 0 20	103 20 0		2 10 10
PRUNU	PRUNUS	PLUM		109 20 30	101 15 10	102 0 35	
				103 35 10			4 18 24
PRAM	P. americana	American plum		70 0 10			1 0 10
PRAN2	P. andersonii	Desert peach		109 10 30			1 10 30
PREM	P. emarginata	Bitter cherry	SW	109 20 40			1 20 40
			NW	3 20 30	102 10 30	71 20 30	
				70 0 10			1 12 25

PROPER USE FACTORS SHRUBS AND TREES (cont.)

PRFA	P. fasciculata	Desert almond		109	10	20							1	10	20
	P. fasiculatus	Desert peach brush		3	20	10							1	20	10
PRIL	P. ilicifolia	Islay		109	20	30							1	20	30
	P. melanocarpa	Black chokecherry	SW	109	10	20	101	15	10	102	0	35			
				103	35	10							4	15	19
			GP	69	10	10							1	10	10
			NW	70	0	10							1	0	10
PRPE2	P. pennsylvanica	Pin cherry		69	10	10							1	10	10
	P. prunifolia	Plumleaf cherry		70	0	10							1	0	10
	P. sabcordiata	Sierra plum		109	30	40							1	30	40
RRVI	P. virginiana	Western chokecherry	SW	109	10	30	101	15	10	102	0	35			
				103	35	10							4	15	21
			GP	108	20	30							1	20	30
			NW	3	10	20	4	15	35	5	0	10			
				107	10	30	6	20	20	7	20	20			
				71	10	20	70	20	40				8	13	24
PSORA	PSORALEA physodes	CALIFORNIA TEA		109	10	10							1	10	10
PTELE	PTELEA baldwinii	WESTERN HOPTREE		109	10	10							1	10	10
PURSH	PURSHIA	BITTERBRUSH		101	50	55	102	45	50	103	50	55	3	52	57
PUTR2	P. tridentata	Bitterbrush	SW	109	60	70	101	50	55	102	45	50			
				103	60	55							4	54	60
			NW	3	40	70	4	25	70	5	45	55			
				20	10	20	21	40	50	22	40	50			
				6	20	40	7	40	50	71	40	50			
				70	20	40	28	40	60	29	20	30			
				40	40	60	41	20	30	42	40	60			
				43	20	30	44	35	50	45	20	25			
				46	30	40	47	15	20	48	25	30			
				49	10	15	50	40	60	51	20	30			
				52	40	60	53	20	30	54	35	50			
				55	20	25	56	30	40	57	15	20			
				58	25	30	58	10	15	59	40	60			
				60	20	30	61	40	60	62	20	30			
				63	35	50	64	20	25	65	30	40			
				66	15	20	67	25	30	68	10	15			
				72	40	60	63	20	30	74	40	60			
				75	20	30	76	35	50	77	20	25			
				78	30	40	79	15	20	80	25	30			
				80	10	15	81	40	60	82	20	30			
				83	40	60	84	20	30	85	35	50			
				86	20	25	87	30	40	88	15	20			
				89	25	30	90	10	15	91	40	60			
				92	20	30	93	10	20	94	20	30			
				95	35	50	96	20	25	97	30	40			
				98	15	20	99	25	30	100	10	15			
QUERC	QUERCUS	OAK		109	10	20							1	10	20
QUAG	Q. agrifolia	Coast live-oak		109	20	20							1	20	20
QUAR	Q. arizonica	Arizona live-oak		109	10	10							1	10	10
QUCH2	Q. chrysolepis	Golden capoak		109	20	20							1	20	20
QUDO	Q. douglasii	Blue oak		109	20	20							1	20	20
QUDU	Q. dumosa	California scrub oak		109	10	20							1	10	20
QUGA	Q. gambelii	Gambel oak		109	20	30	101	15	20	102	20	15			
				103	25	15							4	20	20
QUGA4	Q. garryana	Brewer oak		109	20	30							1	20	30

PROPER USE FACTORS SHRUBS AND TREES (cont.)

QUGR3	Q. grisea	Gray oak		109	10	20							1	10	20
QUKG	Q. kelloggii	Black oak		109	20	30							1	20	30
QULO	Q. lobata	Valley oak		109	10	20							1	10	20
	Q. morehus	Oracle oak		109	20	30							1	20	30
QUTU2	Q. turbinella	Live oak		109	10	20							1	10	20
QUWI2	Q. wislizenii	Interiod live-oak		109	20	20							1	20	20
RHCA	RHAMNUS californica	CALIFORNICA COFFEE-BERRY		109	10	20							1	10	20
RHCR	R. crocea	Red berry		109	20	20							1	20	20
RHPV	R. parshiana	Cascara sagrada	SW	109	0	10							1	0	10
			NW	3	0	10	107	0	10				2	0	10
RHAL2	RHODODENDRON albiflorum	CASCADES AZALEA		71	0	P							1	0	P
RHDI	RHUS diversiloba	POISON OAK		109	40	40							1	40	40
RHGL	R. glabra	Smooth sumac		3	5	10							1	5	10
RHTR	R. trilobata	Squaw bush	SW	109	10	10	102	0	15				2	5	12
			NW	3	0	10	4	0	15	71	0	10	3	0	12
RIBES	RIBES	CURRANT	SW	109	10	20	101	10	0	102	0	10			
				103	15	0							4	9	8
			GP	108	0	10							1	0	10
			NW	3	10	20	4	0	20	6	10	10			
				7	20	20	71	5	20				5	9	18
RIAM2	R. americanum	American black currant		70	10	20							1	10	20
RIAU	R. aureum	Golden currant	SW	101	10	0	102	0	20	103	25	20	3	12	13
			NW	3	10	20	4	10	20	5	0	20	3	7	20
RICE	R. cereum	Wax currant		3	10	20							1	10	20
RIIN2	R. inerme	Whitestem gooseberry		3	10	20							1	10	20
RIPE	R. petiolare	Western black currant		3	10	20							1	10	20
RIVI3	R. viscosissimum	Sticky currant		3	10	20							1	10	20
RONE	ROBINIA neomexicana	LOCUST		109	10	10							1	10	10
ROSA+	ROSA	ROSE	SW	109	20	30	101	15	15	102	0	40			
				103	50	30							4	21	29
			GP	108	20	40							1	20	40
			NW	3	20	40	4	20	55	5	0	30			
				107	30	60	25	20	40	26	20	40			
				6	10	10	7	40	40	71	10	40			
ROAC	R. acicularis	Prickly rose	GP	69	20	40							1	20	40
			NW	70	20	40							1	20	40
	R. alcea			69	20	40							1	20	40
ROBL	R. blanda	Meadow rose		69	20	40							1	20	40
ROCA2	R. californica	California wild rose		109	20	30							1	20	30
	R. chrysocarpa			3	20	40							1	20	40
ROFE	R. fendleri	Fendler rose	SW	109	20	30							1	20	30
			NW	3	20	40							1	20	40
ROGY	R. gymnocarpa	Bald-hip rose		3	20	40	71	20	50				2	20	45
ROWV	R. nutkana	Nutka rose		3	20	40	71	20	40				2	20	40
ROPI2	R. pisocarpa	Peafruit rose		71	20	40							1	20	40
	R. rotundia	Wild rose	SW	101	15	25	102	10	45	103	55	25	3	27	32
			NW	3	25	55	4	20	40	5	10	25	3	18	40
ROSP	R. spaldingii	Spalding rose		3	20	40							1	20	40
	R. suffalta	Sunshine rose		69	20	40							1	20	40
ROWO	R. woodsii	Woods rose		69	20	40							1	20	40
RUBUS	RUBUS	BLACKBERRY	SW	109	10	20							1	10	20
			NW	71	0	10							1	0	10

PROPER USE FACTORS   SHRUBS AND TREES (cont.)

RULE	R. leucodermis	Western blackberry		109 10 20			1 10 10
	R. melanolasius	Western red raspberry	SW	102 0 10	103 10 0		2 5 5
			NW	3 0 10	70 0 40		2 0 25
RUPA	R. parviflorus	Thimbleberry	SW	109 10 20	102 0 10	103 10 0	3 7 10
			NW	3 5 20	107 10 30	71 5 20	
				70 0 10			4 5 20
RUSP	R. spectabilis	Salmonberry	GP	69 0 10			1 0 10
			NW	71 10 40			1 10 40
	R. viburnifolius	Raspberry		70 0 40			1 0 40
RUUR	R. vitifolius	California blackberry		109 10 10			1 10 10
SALIX	SALIX	WILLOW	SW	109 30 40	101 30 30	102 30 45	
				103 45 45			4 34 40
			GP	108 40 70			1 40 70
			NW	3 20 40	4 40 40	5 10 50	
				107 50 60	6 20 40	7 30 40	
				71 20 40			7 27 41
	S. argophylla	Silverleaf willow		70 30 70			1 30 70
	SALTZARIA mexicana	BLADDER SAGE		109 10 10			1 10 10
SALVI	SALVIA	SAGE		109 10 10			1 10 10
SAAP2	S. apiana	White sage		109 10 20			1 10 20
SACA9	S. carnosa	Desert sage	SW	109 20 30	102 20 0	103 30 45	3 23 25
			NW	3 0 20	5 20 45		2 10 32
SAME3	S. mellifera	Black sage		109 10 20			1 10 20
SAMBU	SAMBUCUS	ELDERBERRY	SW	109 30 50	101 30 25	102 0 50	
				103 75 20			4 34 39
			NW	3 20 50	4 10 60	107 40 70	
				6 30 20	7 50 50		5 30 52
	S. coerulea	Blue elderberry	SW	109 40 70	101 30 60	102 0 55	
				103 70 30			4 35 51
			NW	3 20 70	4 30 55		2 25 62
SAGL4	S. glauca	Blue elder		3 20 30	71 40 50		2 30 45
SAMI	S. microbotrys	Bunchberry elder		101 35 25	102 0 20	103 60 0	3 38 15
SAPU3	S. racemosa	Coast red elderberry	SW	109 30 40			1 30 40
			NW	71 40 60	70 10 50		2 25 55
SAPU3	S. racemosa	Blackbead elder	SW	109 40 60	101 30 30	102 0 60	
				103 70 30			4 35 45
			NW	3 70 40	4 30 50	71 40 60	3 47 51
SARCO	SARCOBATUS	GREASEWOOD		101 5 5	102 10 10	103 20 10	3 12 5
SAVE4	S. vermiculatus	Greasewood	SW	109 10 20	101 5 5	102 10 10	
				103 20 10			4 11 11
			GP	108 30 40			1 30 40
			NW	3 0 10	5 10 10	7 10 0	3 7 7
	S. baileyi	Greasewood		109 10 20			1 10 20
	SERICOTHECA discolor	OCEAN SPRAY		70 0 10			1 0 10
SHAR	SHEPHERDIA argentea	SILVER BUFFALOBERRY		109 10 20	101 0 20	103 20 0	3 10 13
SHCA	S. canadensis	Russet buffaloberry		102 0 5			1 0 5
	SORBUS sambucifiolia	SIBERIAN MT. ASH		70 20 30			1 20 30
SOSC2	S. scopulina	Mt. ash	SW	109 10 10			1 10 10
			NW	3 10 15	4 10 60	107 10 30	3 10 35
SOSI2	S. sitchensis	Western Mt. ash	SW	109 10 10	101 10 10	102 0 5	
				103 15 0			4 9 5
			NW	71 0 10			1 0 10
	SPHAERALCEA rivularis	GLOBEMALLOW		70 0 20			1 0 20
SPIRA	SPIRAEA	SPIRAEA		107 0 30	71 0 10		2 0 20

PROPER USE FACTORS — SHRUBS AND TREES (cont.)

SPDE	S. densiflora	Mt. spiraea		3 0 10			1 0 10
SPLU	S. lucida	Birchleaf spiraea		3 0 10	71 5 10		2 2 10
	S. menziesii	Menzies spirea		3 0 10			1 0 10
	STENOTOPSIS linearifolius			109 0 10			1 0 10
	STROMBOCARPA odorata	SCREWBEAN		109 10 10			1 10 10
SYMPH	SYMPHORICARPOS	SNOWBERRY	SW	109 30 40	101 10 15	102 0 30	
				103 20 0			4 15 21
			NW	3 15 20	4 0 20	107 20 60	
				25 10 30	26 10 30	6 10 30	
				7 30 30	71 15 30	50 15 20	
				51 10 15	52 15 20	53 10 15	
				54 5 10	55 5 10	56 5 10	
				57 5 10	58 0 5	58 0 5	
				59 15 20	60 15 20	61 15 20	
				62 15 20	63 5 10	64 5 10	
				65 5 10	66 5 10	67 0 5	
				68 0 5	81 15 20	82 15 20	
				83 15 20	84 15 20	85 5 10	
				86 5 10	87 5 10	88 5 10	
				89 0 5	90 0 5	91 15 20	
				92 15 20	93 15 20	94 15 20	
				95 5 10	96 5 10	97 5 10	
				98 5 10	99 0 5	100 0 5	
SYAL	S. albus	Common snowberry	SW	109 30 30			1 30 30
			NW	3 10 30	70 10 30		2 10 30
SYLO	S. longiflorus	Desert snowberry	SW	109 50 50	101 35 70	102 40 45	
				103 50 50			4 40 54
			NW	3 10 0	4 0 20		2 5 10
SYOC	S. occidentalis	Western snowberry		108 10 20			1 10 20
SYOR2	S. oreophilus	Mt. snowberry	SW	101 10 15	102 0 30	103 20 0	3 10 15
			NW	3 10 30	4 0 20		2 5 25
	S. racemosus		SW	101 10 15	102 0 30	103 20 0	3 10 15
			NW	3 15 20	4 0 20		2 8 20
SYRO	SYMPHORICARPUS rotundifolius	Mt. snowberry	SW	109 20 30	101 10 0	102 0 30	
				103 20 0			4 12 15
			NW	3 0 20	4 0 20		2 0 20
TETRA3	TETRADYMIA	HORSEBRUSH	SW	109 10 10	101 5 10	102 15 0	
				103 15 25			4 11 11
			NW	. 5 10 30			1 10 30
TEAX	T. axillaris	Longspine horsebrush		109 10 10			1 10 10
TECA2	T. canescens	Gray horsebrush	SW	109 10 10	101 5 10	102 15 0	
				103 15 25			4 11 11
			NW	3 0 10	5 15 25		2 8 18
TEGL	T. glabrata	Littleleaf horsebrush	SW	109 10 10	101 5 10	102 15 70	
				103 45 40			4 19 32
			NW	4 0 20	5 10 30		2 5 25
TESP2	T. spinosa	Shortspine horsebrush		109 10 10	101 5 10	102 15 0	
				103 15 25			4 11 11
VACCI	VACCINIUM	HUCKLEBERRY	SW	109 0 10	102 0 15	103 10 0	3 3 8
			NW	3 0 10	4 0 10		2 0 10
VACA	V. caespitosum	Dwarf huckleberry		3 0 10	4 0 10		2 0 10
VADE	V. deliciosum	Delicious blueberry		71 0 10			1 0 10
VAME	V. membranaceum	Big huckleberry		3 0 10	4 0 10	107 0 20	
				71 10 20	70 10 30		5 4 18

PROPER USE FACTORS SHRUBS AND TREES (cont.)

VAOC	V. occidentale	Western bog blueberry		70 10 30			1 10 30
YAMY2	V. oreophilum	Rocky Mt. whortle-berry		70 10 30			1 10 20
VAOV2	V. ovatum	California huckle-berry		109 20 40			1 20 40
VASC	V. scoparium	Grouse huckleberry		4 0 10	107 0 10	71 5 10	3 2 10
VITIS	VITIS	GRAPE		109 10 20			1 10 20
VICA5	V. californica	California wildgrape		109 10 20			1 10 20

APPENDIX III

Diet Composition of Large Herbivores Summarized from Unpublished Bureau of Land Management Data

Appendix Table III.1. Summary of plant species of 5% or more in the diets of herbivores based on fecal analysis for Cedarville District, California. Data are for cattle, horses, deer, sheep, and pronghorn antelope.

CATTLE								
			Cedarville					
			Spring & Summer		Fall & Winter		July 1976-April 1977	
SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	AVERAGE OF THE MEANS n=4	WEIGHTED MEAN AVERAGE n=20	AVERAGE OF THE MEANS n=2	WEIGHTED MEAN AVERAGE n=7	AVERAGE OF THE MEANS n=6	WEIGHTED MEAN AVERAGE n=37
FESTU	Festuca sp.	C_3	35.48	39.05	24.67	30.16	31.88	37.37
AGROP2	Agropyron sp.	C_3	11.37	11.17	9.28	10.39	10.67	11.02
STIPA	Stipa sp.	C_3	9.36	8.55	9.84	12.73	9.52	9.34
SIHY	Sitanion hystrix	C_3	8.39	5.99	5.51	5.88	7.43	5.97
ELYMU	Elymus sp.	C_3	6.13	5.98	22.86	14.00	11.71	7.50
CAREX	Carex sp.	C_3^+	6.02	5.34	11.96	8.94	8.00	6.02
DIST	Distichlis stricta	C_4^+			3.93	5.61		

Appendix Table III.1. (Continued)

			HORSES					
			Cedarville					
			Spring & Summer		Fall & Winter		July 1976-April 1977	
SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	AVERAGE OF THE MEANS n=4	WEIGHTED MEAN AVERAGE n=20	AVERAGE OF THE MEANS n=6	WEIGHTED MEAN AVERAGE n=26	AVERAGE OF THE MEANS n=10	WEIGHTED MEAN AVERAGE n=46
FESTU	Festuca sp.	C_3	38.71	42.38	30.42	32.29	33.74	36.67
STIPA	Stipa sp.	C_3	14.84	14.34	12.77	13.31	13.59	13.76
SIHY	Sitanion hystrix	C_3	10.49	9.57	9.58	8.64	9.94	9.05
AGROP2	Agropyron sp.	C_3	10.33	10.00	13.88	13.77	12.46	12.13
CAREX	Carex sp.	C_3^+	7.00	5.52				
SCIRP	Scirpus sp.	C_3	4.63	5.43				
ARTEM	Artemisia sp.				7.32	7.13		
ELYMU	Elymus sp.	C_3			7.14	6.35	6.04	4.82
POA++	Poa sp.	C_3			7.06	6.49	5.19	4.50

Appendix Table III.1. (Continued)

			DEER					
			Cedarville					
			Spring & Summer		Fall & Winter		July 1976-April 1977	
SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	AVERAGE OF THE MEANS n=	WEIGHTED MEAN AVERAGE n=	AVERAGE OF THE MEANS n=	WEIGHTED MEAN AVERAGE n=	AVERAGE OF THE MEANS n=	WEIGHTED MEAN AVERAGE n=
PUTR2	Purshia tridentata		46.09	52.95	24.38	26.98	33.68	37.80
CELE3	Cercocarpus ledifolius		34.21	29.84	26.79	25.82	29.97	27.50
ARTEM	Artemisia sp.		5.34	4.78	23.12	21.84	15.50	14.73
JUNIP	Juniperus sp.	C_3^+			13.05	12.18	9.11	8.27

Appendix Table III.1. (Continued)

SHEEP			
			Cedarville
			Jul 1976-Apr 1977
SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	AVERAGE OF THE MEANS n=2
FESTU	Festuca sp.	C_3	29.97
LUPIN	Lupinus sp.	C_3	15.44
PERA4	Peraphyllum ramosissimum		10.71
CAREX	Carex sp.	C_3^+	6.88
STIPA	Stipa sp.	C_3	6.62
AGROP2	Agropyron	C_3	6.56
IVAX	Iva axillaris	C_4	5.80

Appendix Table III.1. (Continued)

			ANTELOPE					
			Cedarville					
			Spring & Summer		Fall & Winter		July 1976-April 1977	
SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	AVERAGE OF THE MEANS n=4	WEIGHTED MEAN AVERAGE n=19	AVERAGE OF THE MEANS n=6	WEIGHTED MEAN AVERAGE n-22	AVERAGE OF THE MEANS n=10	WEIGHTED MEAN AVERAGE n=41
ARTEM	Artemisia sp.		42.37	34.29	86.74	85.49	68.99	61.76
PUTR2	Purshia tridentata		26.37	31.77			11.78	16.22
IVAX	Iva axillaris	C_4	8.03	9.70			5.31	6.51

Appendix Table III.2. Summary of plant species comprising less than 5% of the diet of herbivores based on fecal analysis for Cedarville District, California. The data are for cattle, horses, deer, sheep and pronghorn antelope.

CATTLE											
Cedarville											
Spring and Summer				Fall and Winter				July 1976-April 1977			
SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME
POA++	Poa sp.	OENOT	Oenothera sp.	SAKA	Salsola kali	POA++	Poa sp.	POTEN	Potentilla sp.	TRAGA	Tragapogon sp.
PUTR2	Purshla tridentata	VERBA	Verbascum sp.	BROMU	Bromus sp.		Distichlis striata	TETRA3	Tetrademia sp.	TRIFO	Trifolium sp.
MURI	Muhlenbergia richardsonis	POTEN	Potentilla sp.	ARTEM	Artemisia sp.	PUTR2	Purshia tridentata	RIBES	Ribes sp.		Unknown forb
SCIRP	Sclrpus sp.	RIBES	Ribes sp.	POA++	Poa sp.	MURI	Muhlenbergia richardsonis	SYMPH	Symphoricarpos sp.	CHNA2	Chrysothamnus nauseosus
	Distichlis striata	SARCO	Sarcobatus sp.	LUPIN	Lupinus sp.	SCIRP	Scirpus sp.	LITHO3	Lithospermum sp.	ROSA+	Rosa sp.
ARTEM	Artemisia sp.	TETRA3	Tetrademia sp.	IVAX	Iva axillaris	ARTEM	Artemisia sp.		Pod		
JUNCU	Juncus sp.	BALSA	Balsamorhiza sp.	OENOT	Oenothera sp.	BROMU	Bromus sp.	DESCU	Descurainia sp.		
BROMU	Bromus sp.	EUROT	Eurotia sp.	SCIRP	Scirpus sp.	SAKA	Salsola kali	MERTE	Mertensia sp.		
CELE3	Cercocarpus ledifolius	GRAYI	Grayia sp.	TETRA3	Tetrademia sp.	JUNCU	Juncus sp.	GRAYI	Grayia sp.		
IVAX	Iva axillaris	ASTRA	Astragalus sp.	ATRIP	Atriplex sp.	IVAX	Iva axillaris	BALSA	Balsamorhiza sp.		
SAKA	Salsola kali	DESCU	Descurainia sp.	PUTR2	Purshia tridentata	CELE3	Cercocarpus ledifolius	EUROT	Eurotia sp.		
HORDE	Hordeum sp.	SISYM	Sisymbrium sp.	LITHO3	Lithospermum sp.	LUPIN	Lupinus sp.	ASTRA	Astragalus sp.		
ATRIP	Atriplex sp.	LEPID	Lepidium sp.		Pod	OENOT	Oenothera sp.	ERIOG	Eriogonum sp.		
LUPIN	Luplnus sp.		Seed	MURI	Muhlenbergia richardsonis	ATRIP	Atriplex sp.	SISYM	Sisymbrium sp.		
SYMPH	Symphoricarpos sp.	PERA4	Peraphyllum ramosissimum	JUNCU	Juncus sp.	HORDE	Hordeum sp.	PERA4	Peraphyllum ramosissimum		
ORHY	Oryzopsis hymenoides	MERTE	Mertensia sp.	DESCU	Descurainia sp.	SARCO	Sarcobatus sp.	LEPID	Lepidium sp.		
ROSA+	Rosa sp.	DELPH	Delphinium sp.	SARCO	Sarcobatus sp.	ORHY	Oryzopsis hymenoides		Seed		
ERIGE2	Erlgeron sp.		Unknown forb	MERTE	Mertensia sp.	VERBA	Verbascum sp.	AMELA	Amelanchier sp.		
TRIFO	Trifollum	AMELA	Amelanchier sp.	ERIOG	Eriogonum sp.			DELPH	Delphinium sp.		
		CHNA2	Chrysothamnus nauseosus	VERBA	Verbascum sp.			ERIGE2	Erigeron sp.		
		TRAGA	Tragapogon sp.	GRAYI	Grayia sp.						

Appendix Table III.2. (Continued)

HORSES													
Cedarville													
Spring and Summer				Fall and Winter				July 1976-April 1977					
SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME
ELYMU	Elymus sp.	SISYM	Sisymbrium sp.	IVAX	Iva axillaris	SYMPH	Symphoricarpos sp.	ARTEM	Artemisia sp.	SAKA	Salsola kali	DELPH	Delphinium sp.
POA++	Poa sp.	DELPH	Delphinium sp.	CAREX	Carex sp.	MERTE	Mertensia sp.	CAREX	Carex sp.	PUTR2	Purshia tridentata	LEPID	Lepidium sp.
LUPIN	Lupinus sp.	POTEN	Potentilla sp.	ORHY	Oryzopsis hymenoides	SISYR	Sisyrinchium sp.	SCIRP	Scirpus sp.	EQUIS	Equisetum sp.		Lichen
BROMU	Bromus sp.		Unknown forbs	BROMU	Bromus sp.	DESCU	Descurainia sp.	IVAX	Iva axillaris	RIBES	Ribes sp.	PERA4	Peraphyllum ramosissimum
MURI	Muhlenbergia richardsonis	POTR5	Populus tremuloides	BALSA	Balsamorhiza sp.	JUNCU	Juncus sp.	ORHY	Oryzopsis hymenoides	SPHAE	Sphaeralcea sp.	POTR5	Populus tremuloides
CELE3	Cercocarpus ledifolius	LEPIP	Lepidium sp.	SCIRP	Scirpus sp.	ERIOG	Eriogonum sp.	BROMU	Bromus sp.	ARNIC	Arnica sp.	SIDAL	Sidalcea sp.
ORHY	Oryzopsis hymenoides	CREPI	Crepis sp.	LUPIN	Lupinus sp.		Unknown forbs	LUPIN	Lupinus sp.	SISYM	Sisymbrium sp.	SOLAN	Solanum sp.
DENOT	Oenothera sp.	EQUIS	Equisetum sp.	ATRIP	Atriplex sp.	CHNA2	Chrysothamnus nauseosus	BALSA	Balsamorhiza sp.		Unknown forbs		
JUNCU	Juncus sp.	ERIOG	Eriogonum sp.	HORDE	Hordeum sp.	DANTH	Danthonia sp.	MURI	Muhlenbergia richardsonis	SYMPH	Symphoricarpos sp.		
ARTEM	Artemisia sp.	PUTR2	Purshia tridentata	JUNIP	Juniperus sp.		Unknown grass	ATRIP	Atriplex sp.	DESCU	Descurainia sp.		
VERBA	Verbascum sp.	DESCU	Descurainia sp.	SAKA	Salsola kali		Lichen	CELE3	Cercocarpus ledifolius	SISYR	Sisyrinchium sp.		
HORDE	Hordeum sp.			MURI	Muhlenbergia richardsonis	DENOT	Oenothera sp.	JUNCU	Juncus sp.	ECHIN4	Echinochloa sp.		
	Other forbs			PUTR2	Purshia tridentata	SISYM	Sisymbrium sp.	HORDE	Hordeum sp.	ERIOG	Eriogonum sp.		
IVAX	Iva axillaris			RIBES	Ribes sp.	CELE3	Cercocarpus ledifolius	DENOT	Oenothera sp.	POTEN	Potentilla sp.		
JUNIP	Juniperus sp.			SPHAE	Sphaeralcea sp.	PERA4	Peraphyllum ramosissimum	JUNIP	Juniperus sp.	CHNA2	Chrysothamnus nauseosus		
MERTE	Mertensia sp.			ARNIC	Arnica sp.	SIDAL	Sidalcea sp.	VERBA	Verbascum sp.	DANTH	Danthonia sp.		
ECHIN4	Echinochloa sp.			EQUIS	Equisetum sp.	SOLAN	Solanum sp.		Other forbs		Unknown grass		
								MERTE	Mertensia sp.	CREPI	Crepis sp.		

Appendix Table III.2. (Continued)

DEER											
Cedarville											
Spring and Summer				Fall and Winter				July 1976-April 1977			
SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME
JUNIP	Juniperus sp.	AMELA	Amelanchier sp.	FESTU	Festuca sp.	BALSA	Balsamorhiza sp.	FESTU	Festuca sp.	BALSA	Balsamorhiza sp.
SYMPH	Symphoricarpos sp.	CHVI8	Chrysothamnus viscidiflorus	IVAX	Iva axillaris	ALLIU	Allium sp.	PERA4	Peraphyllum ramosissimum	DRABA	Draba sp.
LUPIN	Lupinus sp.	POTEN	Potentilla sp.	PERA4	Peraphyllum ramosissimum	CHVI8	Chrysothamnus viscidiflorus	SYMPH	Symphoricarpos sp.		Lichen
FESTU	Festuca sp.	SCIRP	Scirpus sp.	SYMPH	Symphoricarpos sp.	BROMU	Bromus sp.	IVAX	Iva axillaris	CHVI8	Chrysothamnus viscidiflorus
RIBES	Ribes sp.	BALSA	Balsamorhiza sp.	RIBES	Ribes sp.	ELYMU	Elymus sp.	RIBES	Ribes sp.	BROMU	Bromus sp.
PEPA4	Peraphyllum ramosissimum			VERBA	Verbascum sp.	ERIOG	Eriogonum sp.	LUPIN	Lupinus sp.	ALLIU	Allium sp.
STIPA	Stipa sp.			POA++	Poa sp.	XANTH2	Xanthium sp.	VERBA	Verbascum sp.	SISYM	Sisymbrium sp.
AGROP2	Agropyron sp.			STIPA	Stipa sp.	LEPIO	Lepidium sp.	STIPA	Stipa sp.	ELYMU	Elymus sp.
IVAX	Iva axillaris			CHNA2	Chrysothamnus nauseosus			POA++	Poa sp.	XANTH2	Xanthium sp.
DESCU	Descurainia sp.			CAREX	Carex sp.			AGROP2	Agropyron sp.	SCIRP	Scirpus sp.
	Unknown forbs			AGROP2	Agropyron sp.			OESCU	Oescurainia sp.	ERIOG	Eriogonum sp.
VERBA	Verbascum sp.			DESCU	Descurainia sp.			CAREX	Carex sp.		
SIHY	Sitanion hystrix			POTEN	Potentilla sp.			SIHY	Sitanion hystrix		
LEPID	Lepidium sp.			SIHY	Sitanion hystrix				Unknown forb		
POA++	Poa sp.			LUPIN	Lupinus sp.			CHNA2	Chrysothamnus nauseosus		
PRUNU	Prunus sp.			DRABA	Draba sp.			POTEN	Potentilla sp.		
CAREX	Carex sp.				Lichen			LEPIO	Lepidium sp.		
BROMU	Bromus sp.			AMELA	Amelanchier sp.			AMELA	Amelanchier sp.		
SISYM	Sisymbrium sp.							PRUNU	Prunus sp.		

Appendix Table III.2. (Continued)

SHEEP			
Cedarville			
July 1976-April 1977			
SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME
ARTEM	Atremisia sp.	POTEN	Potentilla sp.
PUTR2	Purshia tridentata	PRUNU	Prunus sp.
		RIBES	Ribes sp.
BROMU	Bromus sp.	SIDA+	Sida sp.
SCIRP	Scirpus sp.	JUNIP	Juniperus sp.
DANTH	Danthonia sp.	SYMPH	Symphoricarpus sp.
ORHY	Oryzopsis hymenoides		
SIHY	Sitanion hystrix		
MURI	Muhlenbergia richardsonis		
POA++	Poa sp.		
CELE3	Cercocarpus ledifolius		
	Pod		
AMELA	Amelanchier sp.		
DRABA	Draba sp.		
SISYM	Sisymbrium sp.		
JUNCU	Juncus sp.		
ERIOG	Eriogonum sp.		
OENOT	Oenothera sp.		

Appendix Table III.2. (Continued)

PRONGHORN ANTELOPE							
Cedarville							
Spring and Summer							
SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME
OENOT	Oenothera sp.	SENEC	Senecio sp.	ASTRA	Astragalus sp.	AGOSE	Agoseris sp.
CELE3	Cercocarpus ledifolius	ERIOG	Eriogonum sp.	BALSA	Balsamorhiza	ARNIC	Arnica sp.
DESCU	Descurainia sp.	POA++	Poa sp.	JUNCU	Juncus sp.	GEUM+	Geum sp.
JUNIP	Juniperus sp.	STIPA	Stipa sp.	POLYG4	Polygonum sp.	SIDA+	Sida sp.
LUPIN	Lupinus sp.	CAREX	Carex sp.	ORHY	Oryzopsis hymenoides		Pod
CHNA2	Chrysothamnus nauseosus	ROSA+	Rosa sp.	VERBA	Verbacum sp.		
PERA4	Peraphyllum ramosissimum	ASTER	Aster sp.	POTR5	Populus tremuloides		
	Unknown forbs	CREPI	Crepis sp.	DELPH	Delphinium sp.		
LEPID	Lepidium sp.	MERTE	Mertensia sp.	ERODI	Erodium sp.		
CHVI8	Chrysothamnus viscidiflorus	SIHY	Sitanion hystrix	LITHO3	Lithospermum sp.		
AGROP2	Agropyron sp.	TRIFO	Trifolium sp.	SISYM	Sisymbrium sp.		
RIBES	Ribes sp.	POTEN	Potentilla sp.	SOLAN	Solanum sp.		
ACHIL	Achillea lanulosa	SIDAL	Sidalcea sp.	AMELA	Amelanchier sp.		
SYMPH	Symphoricarpos sp		Seed	SAKA	Salsola kali		
FESTU	Festuca sp.	BROMU	Bromus sp.	DANTH	Danthonia sp.		
ELYMU	Elymus sp.	MURI	Muhlenbergia richardsonis		Distichlis striata		
		ERIGE2	Erigeron sp.		Unknown grass		
		SCIRP	Scirpus sp.				

Appendix Table III.2. (Continued)

PRONGHORN ANTELOPE							
Cedarville							
July 1976-April 1977							
SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME
DESCU	Descurainia sp.	RIBES	Ribes sp.	POTEN	Potentilla sp.		Distichlis striata
OENOT	Oenothera sp.	CAREX	Carex sp.	SIDAL	Sidalcea sp.		Unknown grass
JUNIP	Juniperus sp.	ELYMU	Elymus sp.	SISYM	Sisymbrium sp.	AGOSE	Agoseris sp.
CELE3	Cercocarpus ledifolius	ACHIL	Achillea lanulosa		Seed	DRABA	Draba sp.
LUPIN	Lupinus sp.	POA++	Poa sp.	SCIRP	Scirpus sp.	GEUM+	Geum sp.
CHNA2	Chrysothamnus nauseosus	ASTER	Aster sp.	ASTRA	Astragalus sp.	HELIA3	Helianthus sp.
SYMPH	Symphoricarpos sp.	BROMU	Bromus sp.	BALSA	Balsamorhiza sp.		Lichen
FESTU	Festuca sp.	EQUIS	Equisetum sp.	ERODI	Erodium sp.	XANTH2	Xanthium sp.
AGROP2	Agropyron sp.	MERTE	Mertensia sp.	ATRIP	Atriplex sp.		Pod
PERA4	Peraphyllum ramosissimum	TRIFO	Trifolium sp.	POTR5	Populus tremuloides	SAKA	Salsola kali
ERIOG	Eriogonum sp.	VERBA	Verbaseum sp.	JUNCU	Juncus sp.	ERIGE2	Erigeron sp.
LEPID	Lepidium sp.	ROSA+	Rosa sp.	DELPH	Delphinium sp.		
	Unknown forbs	MURI	Muhlenbergia richardsonis	LITHO	Lithospermum sp.		
CHVI8	Chrysothamnus viscidiflorus	ORHY	Oryzopsis hymenoides	POLYG4	Polygonum sp.		
STIPA	Stipa sp.	SIHY	Sitanion hystrix	SIDA+	Sida sp.		
SENEC	Senecio sp.	CREPI	Crepis sp.	SOLAN	Solanum sp.		
				AMELA	Amelanchier sp.		
				DANTH	Danthonia		

Appendix Table III.2. (Continued)

PRONGHORN ANTELOPE					
Cedarville					
Fall and Winter					
SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME
IVAX	Iva axillaris	CHVI8	Chrysothamnus viscidiflorus	XANTH2	Xanthium sp.
PUTR2	Purshia tridentata	VERBA	Verbascum sp.		Unknown forbs
DESCU	Descurainia sp.	CELE3	Cercocarpus ledifolius	DANTH	Danthonia sp.
LUPIN	Lupinus sp.	ORHY	Oryzopsis hymenoides	BALSA	Balsamorhiza sp.
SYMPH	Symphoricarpus sp.	LEPID	Lepidium sp.	DRABA	Draba sp.
CHNA2	Chrysothamnus nauseosus	ATRIP	Atriplex sp.	ERIGE2	Erigeron sp.
FESTU	Festuca sp.	ELYMU	Elymus sp.	HELIA3	Helianthus sp.
JUNIP	Juniperus sp.	MURI	Muhlenbergia richardsonis	POTEN	Potentilla sp.
OENOT	Oenothera sp.	POA++	Poa sp.	POTR5	Populus tremuloides
ERIOG	Eriogonum sp.	SIHY	Sitanion hystrix		
STIPA	Stipa sp.	SISYM	Sisymbrium		
AGROP2	Agropyron sp.	RIBES	Ribes sp.		
EQUIS	Equisetum sp.	ERODI	Erodium sp.		
ASTER	Aster sp.		Lichen		
BROMU	Bromus sp.	MERTE	Mertensia sp.		
CAREX	Carex sp.	SIDA+	Sida sp.		
SENEC	Senecio sp.	TRIFO	Trifolium sp.		
PERA4	Peraphyllum ramosissimua				

Appendix Table III.3. Summary of plant species of 5% or more in the diets of herbivores based on fecal analysis for Socorro and Farmington Districts, New Mexico. Data are for cattle, horses and deer.

CATTLE						
			Socorro	Farmington	Socorro and Farmington	
			Summer and Fall			
SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	AVERAGE n=2	AVERAGE n-1	AVERAGE OF THE MEANS	WEIGHTED AVERAGE OF THE MEANS
BOUTE	Bouteloua sp.	C_4	35.68	0.57	18.13	23.98
HILAR	Hilaria sp.	C_4	5.17	27.26	16.22	12.53
SPORO	Sporobolus sp.	C_4	27.30	1.11	14.21	18.57
STIPA	Stipa sp.	C_3	0.89	22.91	11.90	8.23
BROMU	Bromus sp.	C_3		31.97	15.99	10.66

Appendix Table III.3. (Continued)

			HORSES			
			Socorro	Farmington	Socorro and Farmington	
			Summer and Fall			
SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	AVERAGE n=2	AVERAGE n=3	AVERAGE OF THE MEANS n=2	WEIGHTED AVERAGE OF THE MEANS
AGROP2	Agropyron sp.	C_3	1.61	57.88	29.75	35.37
BOUTE	Bouteloua sp.	C_4	44.46	0.10	22.28	17.84
HILAR	Hilaria sp.	C_4	0.72	11.66	6.19	7.28
MUHLE	Muhlenbergia sp.	C_4	10.51		5.26	4.20
SPORO	Sporobolus sp.	C_4	24.75	0.18	12.38	9.94
STIPA	Stipa sp.	C_3	4.63	12.15	8.39	9.14
BROMU	Bromus sp.	C_3		10.51	5.26	6.31

Appendix Table III.3. (Continued)

			DEER			
			Socorro	Farmington	Socorro and Farmington	
			Summer and Fall			
SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	AVERAGE n=2	AVERAGE n=1	AVERAGE OF THE MEANS n=2	WEIGHTED AVERAGE OF THE MEANS
AMELA	Amelanchier sp.			11.13	5.57	3.77
CEMO2	Cercocarpus montanus		64.48	5.81	35.15	44.92
JUNIP	Juniperus sp.	C_3^+	6.02	34.58	20.30	15.54
PINUS	Pinus sp.		3.04	39.84	21.44	15.31
RHUS+	Rhus sp.	C_3^+	16.77		8.39	11.18

Appendix Table III.4. Summary of plant species comprising less than 5% of the diet of herbivores based on fecal analysis for Socorro and Farmington Districts, New Mexico. The data are for cattle, horses, and deer.

CATTLE			
Socorro and Farmington			
Summer and Fall			
SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME
AGROP2	Agropyron sp.	FALL	Fallugia sp.
ARIST	Aristida sp.	GUSA2	Gutierrezia sarothrae
CAREX	Carex sp.	JUNIP	Juniperus sp.
LYCUR	Lycurus sp.	LESQU	Lesquerella sp.
MUHLE	Muhlenbergia sp.	MENTZ	Mentzellia sp.
ORHY	Oryzopsis hymenoides	OENOT	Oenothera sp.
SCLER7	Scleropogon sp.	OPUNT	Opuntia sp.
TRIDE	Tridens sp.	PHORA	Phoradendron sp.
FESTU	Festuca sp.	SPHAE	Sphaeralcea sp.
ARTEM	Atremisia sp.	YUCCA	Yucca sp.
ATRIP	Atriplex sp.		Frob
CEMO2	Cercocarpus montanus		
CROTO	Croton sp.		
CLEOM	Cleome sp.		
DESCU	Descurainia sp.		
EPHED	Ephedra sp.		
ERIOG	Eriogonum sp.		
EUROT	Eurotia sp.		

Appendix Table III.4. (Continued)

HORSES	
Socorro and Farmington	
Summer and Fall	
SCS PLANT CODE	SCIENTIFIC NAME
ARIST	Aristida sp.
CAREX	Carex sp.
POA++	Poa sp.
LYCUR	Lycurus sp.
ORHY	Oryzopsis hymenoides
SCLER7	Scleropogon sp.
TRIDE	Tridens sp.
ARTEM	Artemisia sp.
ATRIP	Atriplex sp.
CEMO2	Cercocarpus brevifolius
EPHED	Ephedra sp.
ERIOG	Eriogonum sp.
EUROT	Eurotia sp.
LESQU	Lesquerella sp.
OPUNT	Opuntia sp.
PINUS	Pinus sp.
SPHAE	Sphaeralcea sp.
	Compositae
	Forb
	Seed

Appendix Table III.4. (Continued)

DEER			
Socorro and Farmington			
Summer and Fall			
SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME
AGROP2	Agropyron sp.		Junusia sp.
CAREX	Carex sp.	LESQU	Lesquerella
ORHY	Oryzopsis hymenoides	PHORA	Phoradendron
		QUERC	Quercus sp.
SPORO	Sporobolus sp.		Sartivellia flaveriae
STIPA	Stipa sp.		
TRIDE	Tridens sp.	SPHAE	Sphaeralcea sp.
BROMU	Bromus sp.	YUCCA	Yucca sp.
FESTU	Festuca sp.		Compositae
ASTER	Aster sp.		Forb
ASTRA	Astragalus sp.		Seed
ATRIP	Atriplex sp.		
BERBE	Berberis sp.		
CHNA2	Chrysothamnus nauseosus		
CROTO	Croton sp.		
EPHED	Ephedra sp.		
ERIOG	Eriogonum sp.		
EUROT	Eurotia sp.		
FALL	Fallugia sp.		

Appendix Table III.5. Summary of plant species of 5% or more in the diets of herbivores based on fecal analysis for Elko, Ely and Winnemucca Districts, Nevada. Data are for cattle, horses, deer, sheep and pronghorn antelope.

CATTLE								
			Elko, Winnemucca, and Ely					
			Spring & Summer		Fall & Winter		Yearly	
SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	AVERAGE OF THE MEANS n=3	WEIGHTED AVERAGE OF	AVERAGE OF THE MEANS n=3	WEIGHTED AVERAGE OF	AVERAGE OF THE MEANS n=2 (1)	WEIGHTED AVERAGE OF THE MEANS
AGROP2	Agropyron sp.	C_3			9.37	8.70	5.00	5.00
BROMU	Bromus sp.	C_3	<5.48	<4.73	6.71	3.90		
HILAR	Hilaria sp.	C_4^+	6.32	6.32			31.03	31.03
ORHY	Oryzopsis hymenoides	C_3	7.01	8.60				
POA++	Poa sp.	C_3	16.13	11.67	13.48	8.34	12.50	12.50
STIPA	Stipa sp.	C_3			11.74	10.62	12.97	12.97
ATRIP	Atriplex sp.		<10.71	<14.14	8.35	8.38		
DESCU	Descurania sp.	C_3^+	6.94	7.60				
EULA5	Eurotia lanata		7.79	8.50	31.95	47.93		

Appendix Table III.5. (Continued)

			HORSES					
			Elko, Winnemucca, and Ely					
			Spring & Summer		Fall & Winter		Yearly	
SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	AVERAGE OF THE MEANS n=3	WEIGHTED AVERAGE OF THE MEANS	AVERAGE OF THE MEANS n=3	WEIGHTED AVERAGE OF THE MEANS	AVERAGE OF THE MEANS n=2 (1)	WEIGHTED AVERAGE OF THE MEANS
AGROP2	Agropyron sp.	C_3	5.52	5.32	18.33	12.41		
BROMU	Bromus sp.	C_3	<7.16	<6.75				
HILAR	Hilaria sp.	C_4^+	5.95	7.93			5.62	7.50
ORHY	Oryzopsis hymenoides	C_3	6.26	6.28				
POA++	Poa sp.	C_3	22.22	16.68			13.00	8.67
STIPA	Stipa sp.	C_3	8.72	8.02	24.28	16.91	28.31	27.41
	Ceratoides lanata		6.35	6.35				
ERIOG	Eriogonum sp.	C_4^+			6.33	3.80	5.00	3.33
EULA5	Eurotia lanata		<11.64	<15.07	<22.72	<40.50	23.68	31.23
PHLOX	Phlox sp.	C_3^+	<7.28	<9.41	5.97	8.35		

Appendix Table III.5. (Continued)

			DEER				
			Elko, Winnemucca, and Ely				Elko Only
			Spring & Summer		Fall & Winter		Yearly
SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	AVERAGE OF THE MEANS n=3	WEIGHTED AVERAGE OF THE MEANS	AVERAGE OF THE MEANS n=2	WEIGHTED AVERAGE OF THE MEANS	AVERAGE
BROMU	Bromus sp.	C_3	10.44	7.83			
CAREX	Carex sp.	C_3^+	8.96	6.72			
ELYMU	Elymus sp.	C_3	5.92	4.44			
ARTEM	Artemisia sp.		27.71	20.78	28.21	28.81	22.00
AMELA	Amelanchier sp.		<7.50	11.25			11.00
CERCO	Cercocarpus sp.				5.65	5.27	
JUNIP	Juniperus sp.	C_3^+			7.14	4.76	
PURSH	Purshia sp.		22.64	27.48	53.05	54.02	49.00

Appendix Table III.5. (Continued)

SHEEP			
			Ely Only
			Fall & Winter
SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	AVERAGE n=2
ATRIP	Atriplex sp.		12.52
ERIOG	Eriogonum sp.	C_4^+	80.69

Appendix Table III.5. (Continued)

ANTELOPE							
			Elko, Winnemucca, and Ely				Ely Only
			Spring & Summer		Fall & Winter		Yearly
SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	AVERAGE OF THE MEANS n=2	WEIGHTED AVERAGE OF THE MEANS	AVERAGE OF THE MEANS n=2	WEIGHTED AVERAGE OF THE MEANS	AVERAGE n=1
POA++	Poa sp.	C_3	4.67	5.60			
ARTEM	Artemisia sp.		73.28	77.01	54.09	54.09	49.22
DESCU	Descurania sp.	C_3^+			43.31	43.31	49.22
SPHAE	Sphaeralcea sp.	C_4	16.18	13.14			

Appendix Table III.6. Summary of plant species comprising less than 5% of the diet of herbivores based on fecal analysis for Elko, Ely and Winnemucca Districts, Nevada. The data are for cattle, horses, deer, pronghorn antelope and sheep.

CATTLE					
SPRING & SUMMER		FALL & WINTER		(4) YEARLY	
SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME
AGROP2	Agropyron	CAREX	Carex	BROMU	Bromus
BOUTE	Bouteloua	ELYMU	Elymus	BOUTE	Bouteloua
	Cyperaceae	FESTU	Festuca	CAREX	Carex
ELYMU	Elymus	HILAR	Hilaria	ELYMU	Elymus
FESTU	Festuca	MUHLE	Muhlenbergia	FESTU	Festuca
KOELE	Koeleria	ORHY	Oryzopsis hymenoides	ORHY	Oryzopsis hymenoides
MUHLE	Muhlenbergia	JUNCU	Juncus	JUNCU	Juncus
JUNCU	Juncus	SITAN	Sitanion	SITAN	Sitanion
SITAN	Sitanion	SPORO	Sporobolus	SPORO	Sporobolus
SPORO	Sporobolus		Unknown grass		Unknown grass
STIPA	Stipa	ARTEM	Artemisia	ARTEM	Artemisia
TRIDE	Tridens	BALSA	Balsamorhiza	ATRIP	Atriplex
ARTEM	Artemisia	BERBE	Berberis	CERCO	Cercocarpus
ASTRA	Astragalus	CERCO	Cercocarpus	DESCU	Descurainia
BALSA	Balsamorhiza		Ceratoides lanata	EULAS	Eurotia lanata
CERCO	Cercocarpus	DESCU	Descurainia	HALOG	Halogeton
	Composite	ELEOC	Eleocharis	JUNIP	Juniperus
EPHED	Ephedra	GRSP	Grayia spinosa	PURSH	Purshia
ERIOG	Eriogonum	HALOG	Halogeton	SPHAE	Sphaeralcea
HALOG	Halogeton	LEPID	Lepidium	SOLAN	Solanum
IVAX	Iva axillaris	LUPIN	Lupinus	SYMPH	Symphoricarpos
JUNIP	Juniperus	OPUNT	Opuntia		Unknown legume
LEPID	Lepidium	PHLOX	Phlox	MUHLE	Muhlenbergia
LEPTO2	Leptodactylon	SISYM	Sisymbrium	EQUIS	Equisetum
LESQU	Lesquerella		Unknown composite Artemsia type	ELEOC	Eleocharis
MERTE	Mertensia		Seed	HOLOD	Holodiscus
PHLOX	Phlox		Moss	PHLOX	Phlox
PINUS	Pinus	EQUIS	Equisetum	CHRYS9	Chrysothamnus
PURSH	Purshia	HOLOD	Holodiscus	ERIOG	Eriogonum
SAKA	Salsoa kali	CHRYS9	Chrysothamnus	LEPTO2	Leptodactylon
SAVE4	Sarcobatus vermiculatus	ATRIP	Atriplex	OPUNT	Opuntia
SISYM	Sisymbrium	ERIOG	Eriogonum	TETRA3	Tetradymia
SOLAN	Solanum	LEPTO2	Leptodactylon	LEPID	Lepidium
SYMPH	Symphoricarpos	JUNIP	Juniperus		Composite
	Unknown borage	TETRA3	Tetradymia	PENST	Penstemon
	Unknown composite		Composite	ASTRA	Astragalus
	Unknown composite Artemsia type	PENST	Penstemon	BALSA	Balsamorhiza
	Unknown forb	ASTRA	Astragalus	BORAG	Borago
	Unknown legume	BORAG	Borago	ASTER	Aster
	Seed	ASTER	Aster		
	Unknown chenopod				
	Moss				
EQUIS	Equisetum				
ELEOC	Eleocharis				
HOLO	Holodiscus				
CHRYS9	Chrysothamnus				
ATRIP	Atriplex				
EULAS	Eurotia lanata				
OPUNT	Opuntia				
TETRA3	Tetradymia				
PENST	Penstemon				
BORAG	Borago				
DESCU	Descurainia				
ASTER	Aster				

Appendix Table III.6. (Continued)

HORSES						DEER					
SPRING & SUMMER		FALL & WINTER		YEARLY		SPRING & SUMMER		FALL & WINTER		(1) YEARLY	
SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME
BOUTE	Bouteloua	BROMU	Bromus	AGROP2	Agropyron	AGROP2	Agropyron	AGROP2	Agropyron	AGROP2	Agropyron
CAREX	Carex	BOUTE	Bouteloua	BROMU	Bromus	ORHY	Oryzopsis hymenoides	BROMU	Bromus	STIPA	Stipa
ELYMU	Elymus	CAREX	Carex	BOUTE	Bouteloua	POA↔	Poa	SITAN	Sitanion	BALSA	Balsamorhiza
FESTU	Festuca	ELYMUS	Elymus	CAREX	Carex	SITAN	Sitanion	STIPA	Stipa	CERCO	Cercocarpus
KOELE	Koeleria	DISTI	Distichlis	ELYMU	Elymus	STIPA	Stipa	BALSA	Balsamorhiza	DESCU	Descurainia
MUHLE	Muhlenbergia	FESTU	Festuca	FESTU	Festuca	ASTRA	Astragalus	COMAN	Comandra	HOLOD	Holodiscus
SITAN	Sitanion	HILAR	Hilaria	KOELE	Koeleria	BALSA	Balsamorhiza	CRYPT	Cryptantha	LUPIN	Lupinus
SPORO	Sporobolus	KOELE	Koeleria	ORHY	Oryzopsis hymenoides	CERCO	Cercocarpus	DESCU	Descurainia	SYMPH	Symphoricarpos
ARTEM	Artemisia	ORHY	Oryzopsis hymenoides	SITAN	Sitanion	CHVI8	Chrysothamnus viscidiflorus	LUPIN	Lupinus	BROMU	Bromus
ATRIP	Atriplex	POA↔	Poa	SPORO	Sporobolus						
ASTRA	Astragalus	SITAN	Sitanion		Unknown grass	DESCU	Descurainia	LESQU	Lesquerella	CAREX	Carex
BALSA	Balsamorhiza	SPORO	Sporobolus	ARIST	Aristida	ERIOG	Eriogonum	PHLOX	Phlox	ORHY	Oryzopsis hymenoides
	Brassicaceae		Unknown grass	ARTIP	Atriplex	EULAS	Eurotia lanata	SYMPH	Symphoricarpos	POA↔	Poa
CHVI8	Chrysothamnus viscidiflorus	ARTEM	Artemisia	GRSP	Grayia soinosa	HOLOD	Holodiscus	CAREX	Cares	SITAN	Sitanion
DESCU	Descurainia	ATRIP	Atriplex	PHLOX	Phlox	JUNIP	Juniperus	ORHY	Oryzopsis hymenoides	ATRIP	Atriplex
EPHED	Ephedra	CRYPT	Cryptantha	TETRA3	Tetradymia	LUPIN	Lupinus	POA↔	Poa	BERBE	Berberis
ERIOG	Eriogonum	DESCU	Descurainia		Unknown forb	PHLOX	Phlox	ATRIP	Atriplex	LEPTO2	Leptodactylon
LEPID	Lepidium	DRABA	Draba		Seed	SYMPH	Symphoricarpos	BERBE	Berberis	CHRYS9	Chrysothamnus
LUPIN	Lupinus	ERYSI	Erysimum		Unknown chenopod	BROMU	Bromus	LEPTO2	Leptodactylon	PRUNU	Prunus
PINUS	Pinus	GRSP	Grayia spinosa	JUNCU	Juncus	CAREX	Carex	CHRYS9	Chrysothamnus	ASTER	Aster
SAVE4	Sarcobatus vermiculatus	LEPID	Lepidium	EQUIS	Equisetum	ATRIP	Atriplex	PRUNU	Prunus	ASTRA	Astragalus
TETRA3	Tetradymia	LEPTO2	Leptodactylon	MUHLE	Muhlenbergia	BERBE	Berberis	ASTER	Aster	BORAG	Borago
	Unknown forb	LUPIN	Lupinus	CHRYS9	Chrysothamnus	LEPTO2	Leptodactylon	ASTRA	Astragalus	CRYPT	Cryptantha
	Unknown chenopod	PINUS	Pinus	PURSH	Purshia	PRUNU	Prunus	BORAG	Borago	OENOT	Oenothera
JUNCU	Juncus	SAKA	Salsoa kali	SALSO	Salsola	ASTER	Aster	OENOT	Oenothera		
EQUIS	Equisetum	SAVE4	Sarcobatus vermiculatus	PENST	Penstemon	BORAG	Borago				
PURSH	Purshia	SPHAE	Sphaeralcea	BALSA	Balsamorhiza	OENOT	Oenothera				
SALSO	Salsola	TETRA3	Tetradymia								
PENST	Penstemon		Unknown composite Artemsia type								
			Unknown forb								
			Unknown legume								
		JUNCU	Juncus								
		EQUIS	Equisetum								
		MUHLE	Muhlenbergia								
		CHRYS9	Chrysothamnus								
		PURSH	Purshia								
		SALSO	Salsola								
		PENST	Penstemon								
		BALSA	Balsamorhiza								

Appendix Table III.6. (Continued)

ANTELOPE						SHEEP					
(2) SPRING & SUMMER		(2) FALL & WINTER		(3) YEARLY		SPRING & SUMMER		(3) FALL & WINTER		YEARLY	
SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME
AGROP2	Agropyron	DISTI	Distichlis		Unknown grass			AGROP2	Agropyron		
ELYMU	Elymus	HILAR	Hilaria	ATRIP	Atriplex			BROMU	Bromus		
HILAR	Hilaria	POA++	Poa	OPUNT	Opuntia			HILAR	Hilaria		
ORHY	Oryzopsis hymenoides		Unknown grass	SPHAE	Sphaeralcea			ORHY	Oryzopsis hymenoides		
SITAN	Sitanion	ATRIP	Atriplex		Unknown legume			SITAN	Sitanion		
SPORO	Sporobolus	CHVI8	Chrysothamnus viscidiflorus					SPORO	Sporobolus		
ATRIP	Atriplex							STIPA	Stipa		
ASTRA	Astragalus	ERIGE2	Erigeron					ARTEM	Artemisia		
ASTER	Aster	OPUNT	Opuntia					BALSA	Balsamorhiza		
BALSA	Balsamorhiza	PHLOX	Phlox					DESCU	Descurainia		
	Ceratoides lanata	SPHAE	Sphaeralcea					EPHED	Ephedra		
CHVI8	Chrysothamnus viscidiflorus		Unknown forb					GRSP	Gravia spinosa		
DESCU	Descurainia							HALOG	Halogeton		
ERIOG	Eriogonum							OPUNT	Opuntia		
EULAS	Eurotia lanata							PHLOX	Phlox		
GERAN	Geranium							SPHAE	Sphaeralcea		
IVAX	Iva axillaris								Unknown forb		
LEPID	Lepidium										
LEPTO2	Leptodactylon										
LESQU	Lesquerella										
OPUNT	Opuntia										
KOSC	Kochia scoparia										
OENOT	Oenothera										
PHLOX	Phlox										
SAVE4	Sarcobatus vermiculatus										
	Unknown forb										
	Unknown legume										
	Seed										

(1) Elko only
(2) Does not include Ely
(3) Ely only
(4) Does not include Winnemucca

Appendix Table III.7. Summary of plant species of 5% or more in the diets of herbivores based on fecal analysis for Salt Lake City and Cedar City Districts, Utah. Data are for cattle, horses and deer.

			CATTLE				
			Cedar City				SALT LAKE CITY
			WINTER	SUMMER	YEARLONG OR UNSPECIFIED SEASON		SEP 29-DEC 22
SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	AVERAGE	AVERAGE	WEIGHTED AVERAGE OF THE MEANS	AVERAGE OF THE MEANS	AVERGE
AGROP2	Agropyron sp.	C_3					12.19
ARIST	Aristida sp.	C_4^+	7.65				
BOUTE	Bouteloua sp.	C_4		10.79			
BROMU	Bromus sp.	C_3			3.99	5.30	
CAREX	Carex sp.	C_3^+					9.50
FESTU	Festuca sp.	C_3	5.91				
HILAR	Hilaria sp.	C_4^+			11.65	23.67	
KOELE	Koeleria sp.	C_3^+					10.59
SPORO	Sporobolus	C_4^+		6.17	8.53	6.91	
STIPA	Stipa sp.	C_3		6.14	6.67	12.95	37.87
ATRIP	Atriplex sp.		12.66		5.55	3.61	
	Ceratoides sp.		13.50	13.85			
EPHED	Ephedra sp.		23.37	10.27	8.15	5.30	
FRANS	Franseria sp.	C_4	8.54				
GLOSS	Glossopetalon sp			5.62			
PURSH	Purshia sp.						5.31
QUERC	Quercus sp.			12.77	23.00	14.95	
SHEPH	Shepherdia sp.			13.58	8.53	5.55	
	Totals		71.63	79.19	76.07	78.24	75.46

Appendix Table III.7. (Continued)

			HORSE					
			CEDAR CITY				SALT LAKE CITY	
			UNSPECIFIED SEASON		SUMMER		UNSPECIFIED SEASON	
SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	WEIGHTED AVERAGE OF THE MEANS	AVERAGE OF THE MEANS	WEIGHTED AVERAGE OF THE MEANS	AVERAGE OF THE MEANS	WEIGHTED AVERAGE OF THE MEANS	AVERAGE OF THE MEANS
AGROP2	Agropyron sp.	C_3	19.82	21.54	7.04	7.38	37.88	42.43
BROMU	Bromus sp.	C_3	12.41	11.18	9.01	9.48	5.23	6.96
SPORO	Sporobolus sp.	C_3^+			14.41	13.22		
STIPA	Stipa sp.	C_3	46.34	44.82	25.23	24.30	18.35	12.85
	Ceratoides sp.				32.06	33.50		
EUROT	Eurotia sp.		6.44	7.25			27.45	28.90
	Totals		85.01	84.79	87.75	87.88	88.91	91.14

Appendix Table III.7. (Continued)

			DEER		
			CEDAR CITY		SALT LAKE CITY
			SUMMER		SEP 29-DEC 22
SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	WEIGHTED AVERAGE OF THE MEANS	AVERAGE OF THE MEANS	AVERAGE
ARTEM	Artemisia sp.		14.35	16.66	24.98
CERCO	Cercocarpus sp.		4.95	5.84	10.88
COWAN	Cowania sp.	C_3	2.69	5.37	
JUNIP	Juniperus sp.	C_3^+	22.53	21.16	32.17
PINUS	Pinus sp.		6.89	13.10	
PURSH	Purshia sp.		18.42	12.28	9.72
QUERC	Quercus sp.		22.02	14.68	
	Totals		91.85	89.09	77.75

Appendix Table III.8. Summary of the plant species comprising less than 5% of the diet of herbivores based on fecal analysis for Salt Lake City and Cedar City, Utah. The data are for cattle, deer and horses.

CATTLE													
CEDAR CITY										SALT LAKE CITY			
WINTER		SUMMER				YEARLONG OR UNSPECIFIED SEASON				SEP 29-DEC 22			
SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME
AGROP2	Agropyron	AGROP2	Agropyron	YUCCA	Yucca	AGROP2	Agropyron	YUCCA	Yucca	BOUTE	Bouteloua	(BERBE)	Mahonla
BOUTE	Bouteloua	ARIST	Arlstida			ARIST	Arlstida			BROMU	Bromus	MERTE	Mertensia
BROMU	Bromus	BROMU	Bromus			BOUTE	Bouteloua			DESCH	Deschampsia		Moss
HILAR	Hilaria	CAREX	Carex			CAREX	Carex			ELYMU	Elymus	PHLOX	Phlox
KOELE	Koeleria	ELEOC	Eleocharis			JUNCU	Juncus			FESTU	Festuca	PHORA	Phoradenron
MUHLE	Muhlenbergia	ELYMU	Elymus			MUHLE	Muhlenbergia			JUNCU	Juncus	SHEPH	Shepherdia
ORYZO	Oryzopsis	HILAR	Hilaria			ORYZO	Oryzopsls			MUHLE	Muhlenbergla	SPHAE	Sphaeralcea
SITAN	Sitanion	JUNCU	Juncus			POA++	Poa			ORYZO	Oryzopsls	SYMPH	Symphoricarpos
STIPA	Stipa	MUHLE	Muhlenbergia			SITAN	Sitanlon			POA++	Poa	TETRA3	Tetradymia
ARTEM	Artemisia	ORYZO	Oryzopsis			AMELA	Amelanchier			SITAN	Sitanion	VERBE	Verbascum
ASTRA	Astragalus	POA++	Poa			ARTEM	Artemisia			SPORO	Sporobolus		
COWAN	Cowania	AGAVE	Agave			ASTRA	Astragalus			AMELA	Amelanchier		
CRYPT	Cryptantha	ARTEM	Artemisia				Ceratoides			ARTEM	Artemisia		
DESCU	Oescurainia	ASTRA	Astragalus				Composite			ASTRA	Astragalus		
EROOI	Erodlum	ATRIP	Atriplex			COWAN	Cowania			ATRIP	Atriplex		
JUNIP	Juniperus	CERCO	Cercocarpus			DESCU	Descuralnia				Borage		
KRAME	Krameria	EQUIS	Equisetum			EQUIS	Equisetum			CEANO	Ceanothus		
LESQU	Lesquerella	GARRY	Garrya			JUNIP	Juniperus			CERCO	Cercocarpus		
PHORA	Phoradendron	JUNIP	Juniperus			LESQU	Lesquerella			CHRYS9	Chrysothamnus		
	Seed	MARRU	Marrubium			MENTZ	Mentzella				Composite		
SPHAE	Sphaeralcea	OPUNT	Opuntla			OPUNT	Opuntia			CRYPT	Cryptantha		
		PHLOX	Phlox			PHLOX	Phlox			EQUIS	Equisetum		
		PHORA	Phoradendron			PHORA	Phoradendron			ERIOG	Eriogonum		
		PURSH	Purshia			PURSH	Purshla				Ceratoides		
		SPHAE	Sphaeralcea			SPHAE	Sphaeralcea			KOCHI	Kochia		
		SYMPH	Symphoricarpos			SYMPH	Symphorlcarpos			LEPTO2	Leptodactylon		
		TETRA3	Tetradymia			TETRA3	Tetradymia			LUPIN	Lupins		

Appendix Table III.8. (Continued)

DEER						HORSE							
CEDAR CITY		SALT LAKE CITY				CEDAR CITY						SALT LAKE CITY	
SUMMER		SEP 29-DEC 22				SUMMER		UNSPECIFIED SEASON				UNSPECIFIED SEASON	
SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME
BOUTE	Bouteloua	AGROP2	Agropyron		Moss	ARIST	Aristida	ARIST	Aristida		Unknown Composite	BOUTE	Bouteloua
BROMU	Bromus	BROMU	Bromus	PHLOX	Phlox								
CAREX	Carex	CAREX	Carex	PHORA	Phoradendron	BOUTE	Bouteloua	BOUTE	Bouteloua		Unknown forb	CAREX	Carex
KOELE	Koeleria	JUNCU	Juncus	SHEPH	Shepherdia	CAREX	Carex	CAREX	Carex		Unknown legume	ELYMU	Elymus
ORYZO	Oryzopsis	KOELE	Koeleria	SPHAE	Sphaeralcea	DESCH	Deschampsia	ELEOC	Eleocharis			HILAR	Hilaria
POA++	Poa	MUHLE	Muhlenbergia	SYMPH	Symphoricarpos	ELEOC	Eleocharis	ELYMU	Elymus			KOELE	Koeleria
SPORO	Sporobolus	ORYZO	Oryzopsis	TETRA3	Tetradymia	ELYMU	Elymus	HILAR	Hilaria			ORYZO	Oryzopsis
STIPA	Stipa	POA++	Poa	VERBA	Verbascum	FESTU	Festuca	JUNCU	Juncus			POA++	Poa
ASTRA	Astragalus	SITAN	Sitanion			HILAR	Hilaria	KOELE	Koeleria			SITAN	Sitanion
ATRIP	Atriplex	SPORO	Sporobolus			KOELE	Koeleria	ORYZO	Oryzopsis			SPORO	Sporobolus
	Ceratodies	STIPA	Stipa			MUHLE	Muhlenbergia	POA++	Poa			(FESTU)	Vulpia
CHRYS9	Chrysothumnus	AMELA	Amelanchier			ORYZO	Oryzopsis	SITAN	Sitanion			ARTEM	Artemisia
DESCU	Descurainia	ASTRA	Astragalus			POA++	Poa	SPORO	Sporobolus			ATRIP	Atriplex
EPHED	Ephedra	ATRIP	Atriplex			SITAN	Sitanion	(FESTU)	Vulpia			DESCU	Descurainia
ERODI	Erodium	BALSA	Balsamorhiza			ARTEM	Artemisia	ARTEM	Artemisia			EPHED	Ephedra
LESQU	Lesquerella	CEANO	Ceanothus			ASTRA	Astragalus	ATRIP	Atriplex			JUNIP	Juniperus
(BERBE)	Mahonia		Composite			ATRIP	Atriplex		Ceratoides			LUPIN	Lupinus
PENST	Penstemon	CRYPT	Cryptantha				Composite	EPHED	Ephedra			OPUNT	Opuntia
PHORA	Phoradendron	DESCU	Descurainia			EPHED	Ephedra	ERIGE2	Erigeron			PHLOX	Phlox
PLANT	Plantago	EQUIS	Equisetum			ERIOG	Eriogonum	JUNIP	Juniperus			PURSH	Purshia
SPHAE	Sphaeralcea	ERIOG	Eriogonum			JUNIP	Juniperus		Lilacea			SPHAE	Sphaeralcea
	Unknown forb	EUROT	Eurotia			LEPTO2	Leptodactylon	LUPIN	Lupinus			TETRA3	Tetradymia
		LEPTO2	Leptodactylon			LUPIN	Lupinus	OPUNT	Opuntia				Unknown Composite
		LESQU	Lesquerella			PHLOX	Phlox	PHLOX	Phlox				Unknown forb
		LUPIN	Lupinus				Unknown forb	PURSH	Purshia				Unknown legume
		(BERBE)	Mahonia				Unknown legume	QUERC	Quercus				Moss
		MERTE	Mertensia					SPHAE	Sphaeralcea				Arthropod.
								TETRA3	Tetradymia				

Appendix Table III.9. Summary of plant species of 5% or more in the diets of herbivores based on fecal analysis for Rock Springs and Rawlins Districts, Wyoming. Data are for cattle, horses, deer, elk, sheep, bighorn sheep and pronghorn antelope.

CATTLE						
			Rock Springs & Rawlins		Rock Springs Only	
			Spring & Summer		Fall & Winter	Yearly
SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	AVERAGE OF THE MEANS	WEIGHTED AVERAGE OF THE MEANS	AVERAGE n=7	AVERAGE n=1
AGROP2	Agropyron sp.	C_3	30.34	30.34	17.49	54.00
CAREX	Carex sp.	C_3^+	10.34	10.34		
ORHY	Oryzopsis hymenoides	C_3	7.50	7.50		9.00
STIPA	Stipa sp.	C_3	20.94	20.94	24.86	11.00
ATRIP	Atriplex sp.					9.00
EUROT	Eurotia sp.					5.00

Appendix Table III.9. (Continued)

			HORSES			
			Rock Springs & Rawlins		Rock Springs Only	
			Spring & Summer		Fall & Winter	Yearly
SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	AVERAGE OF THE MEANS	WEIGHTED AVERAGE OF THE MEANS	AVERAGE n=6	AVERAGE n=1
AGROP2	Agropyron sp.	C_3	13.54	21.69	15.76	37.0
CAREX	Carex sp.	C_3^+				5.0
ORHY	Oryzopsis hymenoides	C_3	5.42	8.67		10.0
STIPA	Stipa sp.	C_3	70.42	55.49	31.77	36.0
ATRIP	Atriplex sp.				5.60	
EUROT	Eurotia sp.				18.01	

Appendix Table III.9. (Continued)

DEER				
			Rawlins Only	
			Spring & Summer	Fall & Winter
SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	AVERAGE n=2	AVERAGE n=4
STIPA	Stipa sp.	C_3	6.46	
ARTEM	Artemisia sp.		56.43	75.95
CEMO2	Cercocarpus montanus		15.53	9.16

Appendix Table III.9. (Continued)

			ELK				
			Rock Springs & Rawlins				Rock Springs Only
			Spring & Summer		Fall & Winter		Yearly
SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	AVERAGE OF THE MEANS n=2	WEIGHTED AVERAGE OF THE MEANS	AVERAGE OF THE MEANS n=2	WEIGHTED AVERAGE OF THE MEANS	AVERAGE n=1
AGROP2	Agropyron sp.	C_3	13.52	19.39	19.87	20.91	46.00
STIPA	Stipa sp.	C_3	41.94	39.77	10.45		2.22
ARTEM	Artemisia sp.		8.61		9.18	8.63	
CEMO2	Cercocarpus montanus				7.24		
ERIOG	Eriogonum sp.	C_4^+	7.10				
LUPIN	Lupinus sp.	C_3			12.11	18.17	
PSEUD7	Pseudotsuga sp.				11.53	5.77	

Appendix Table III.9. (Continued)

			SHEEP		
			Rock Springs Only		
			Spring & Summer	Fall & Winter	Yearly
SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	AVERAGE n=4	AVERAGE n=6	AVERAGE n=1
AGROP2	Agropyron sp.	C_3	6.46	7.85	14.00
STIPA	Stipa sp.	C_3	19.97	12.67	22.00
ATRIP	Atriplex sp.		36.08	40.49	47.00
EUROT	Eurotia sp.		7.24	24.13	

Appendix Table III.9. (Continued)

BIGHORN SHEEP				
			Rawlins Only	
			Spring & Summer	Fall & Winter
SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	AVERAGE n=9	AVERAGE n=7
AGROP2	Agropyron sp.	C_3	5.97	26.01
STIPA	Stipa sp.	C_3	27.01	14.69
CEMO2	Cercocarpus montanus		24.95	

Appendix Table III.9. (Continued)

ANTELOPE						
			Rock Springs & Rawlins		Rock Springs Only	
			Spring & Summer		FALL & WINTER	Yearly
SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	AVERAGE OF THE MEANS	WEIGHTED AVERAGE OF THE MEANS	AVERAGE n=7	AVERAGE n=1
ARTEM	Artemisia sp.		34.29	36.96	72.73	78.00
ASTRA	Astragalus sp.	C_3^+		6.12		
CEMO2	Cercocarpus montanus		12.15	10.80		
ATRIP	Atriplex sp.					6.00
ERIOG	Eriogonum sp.	C_4^+	10.68	9.57		

Appendix Table III.10. Summary of plant species comprising less than 5% of the diet of herbivores based on fecal analysis for Rock Springs and Rawlins Districts, Wyoming. The data are for cattle, horses, deer, elk, sheep, bighorn sheep and pronghorn antelope.

CATTLE					
SPRING & SUMMER		(1) FALL & WINTER		(1) YEARLY	
SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME
BOUTE	Bouteloua	ARIST	Aristida	BROMU	Bromus
BROMU	Bromus	BOUTE	Bouteloua	CAREX	Carex
ELYMU	Elymus	BROMU	Bromus	POA++	Poa
FESTU	Festuca	CAREX	Carex	(FEOC2)	Vulpia octiflora
KOELE	Koeleria	ELYMU	Elymus	DIST	Distichlis stricta
POA++	Poa	FESTU	Festuca	AMELA	Amelanchier
SITAN	Sitanion	KOELE	Koeleria	CHRYS9	Chrysothamnus
MUHLE	Muhlenbergia	ORHY	Oryzopsis hymenoides	CRYPT	Cryptantha
(FEOC2)	Vulpia octiflora	POA++	Poa	LESQU	Lesquerella
SPORO	Sporobolus	SITAN	Sitanion	PURSH	Purshia
HESPE5	Hesperochloa	(FEOC2)	Vulpia octiflora	SYMPH	Symphoricarpos
ATRIP	Atriplex				
AMELA	Amelanchier				
BERBE	Berberis				
CEMO2	Cercocarpus montanus				
CRYPT	Cryptantha				
ERIGE2	Erigeron				
ERIOG	Eriogonum				
ELUA5	Eurotia lanata				
EQUIS	Equisetum				
HALOG	Halogton				
LEPTO2	Leptodactylon				
LUPIN	Lupinus				
OPUNT	Opuntia				
OENOT	Oenothera				
PURSH	Purshia				
PINUS	Pinus				
SHEPH	Shepherdia				

Appendix Table III.10. (Continued)

HORSES					
SPRING & SUMMER		(1) FALL & WINTER		(1) YEARLY	
SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME
BOUTE	Bouteloua	BROMU	Bromus	BROMU	Bromus
BROMU	Bromus	CAREX	Carex	POA++	Poa
CAREX	Carex	ELYMU	Elymus	(FEOC2)	Vulpia octiflora
ELYMU	Elymus	FESTU	Festuca	SPORO	Sporobolus
FESTU	Festuca	KOELE	Koeleria	DIST	Distichlis stricta
KOELE	Koeleria	ORHY	Oryzopsis hymenoides	ARTEM	Artemisia
POA++	Poa	POA++	Poa	ATRIP	Atriplex
SITAN	Sitanion	SITAN	Sitanion	CHRYS9	Chrysothamnus
SPORO	Sporobolus	(FEOC2)	Vulpia octiflora	ELUA5	Eurotia lanata
ARTEM	Artemisia	ARTEM	Artemisia	SARCO	Sarcobotus
ASTRA	Astragalus	CHRYS9	Chrysothamnus	SYMPH	Symphoricarpos
ATRIP	Atriplex	GRAYI	Grayia	SPHAE	Sphaeralcea
CHRYS9	Chrysothamnus	HALOG	Halogeton	SAKA	Salsoa kali
DESCU	Descurainia	LUPIN	Lupinus		
ERIOG	Eriogonum	OPUNT	Opuntia		
EULA5	Eurotia lanata	SARCO	Sarcobotus		
GRSQ	Grindelia squarrosa	SYMPH	Symphoricarpos		
LEPTO2	Leptodactylon	SPHAE	Sphaeralcea		
SARCO	Sarcobotus	SAKA	Salsoa kali		
RHUS+	Rhus	TETRA3	Tetradymia		

Appendix Table III.10. (Continued)

DEER					
(2) SPRING & SUMMER		(2) FALL & WINTER		YEARLY	
SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME
AGROP2	Agropyron	AGROP2	Agropyron		
CAREX	Carex	CAREX	Carex		
KOELE	Koeleria	ELYMU	Elymus		
SITAN	Sitanion	KOELE	Koeleria		
ASTRA	Astragalus	POA++	Poa		
ATRIP	Atriplex	SITAN	Sitanion		
BERBE	Berberis	STIPA	Stipa		
DESCU	Descurainia	ATRIP	Atriplex		
ERIGE2	Erigeron	BERBE	Berberis		
ERIOG	Eriogonum	CRYPT	Cryptantha		
JUNIP	Juniperus	ERIGE2	Erigeron		
LEPTO2	Leptodactylon	JUNIP	Juniperus		
LESQU	Lesquerella	LEPTO2	Leptodactylon		
LUPIN	Lupinus	LESQU	Lesquerella		
OPUNT	Opuntia	OPUNT	Opuntia		
PURSH	Purshia	PURSH	Purshia		
PINUS	Pinus	PINUS	Pinus		
	Unknown composite	PSEUD7	Pseudostuga		

Appendix Table III.10. (Continued)

ELK					
SPRING & SUMMER		FALL & WINTER		(1) YEARLY	
SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME
BOUTE	Bouteloua	BOUTE	Bouteloua	BROMU	Bromus
BROMU	Bromus	BROMU	Bromus	CAREX	Carex
CAREX	Carex	CAREX	Carex	ORHY	Oryzopsis hymenoides
ELYMU	Elymus	ELYMU	Elymus	POA++	Poa
FESTU	Festuca	FESTU	Festuca	(FEOC2)	Vulpia octiflora
KOELE	Koeleria	KOELE	Koeleria	SPORO	Sporobolus
ORHY	Oryzopsis hymenoides	ORHY	Oryzopsis hymenoides	DIST	Distichlis stricta
POA++	Poa	POA++	Poa	ARTEM	Artemisia
SITAN	Sitanion	SITAN	Sitanion	ASTRA	Astragalus
(FEOC2)	Vulpia octiflora	(FEOC2)	Vulpia octiflora	ATRIP	Atriplex
ASTRA	Astragalus	SPORO	Sporobolus	CHRYS9	Chrysothamnus
ATRIP	Atriplex	ASTRA	Astragalus	CRYPT	Cryptantha
AMELA	Amelanchier	ATRIP	Atriplex	EULA5	Eurotia lanata
	Boraginaceae	AMELA	Amelanchier	ELAEA	Elaeagnus
CEMO2	Cercocarpus montanus	AMPHI3	Amphipappus	LESQU	Lesquerella
CHRYS9	Chrysothamnus	BERBE	Berberis	SARCO	Sarcobotus
ERIGE2	Erigeron	CHRYS9	Chrysothamnus	SAKA	Salsoa kali
EULA5	Eurotia lanata	CRYPT	Cryptantha	ROSA+	Rosa
ELAEA	Elaeagnus	DESCU	Descurainia		
LEPTO2	Leptodactylon	ERIOG	Eriogonum		
LESQU	Lesquerella	GRAYI	Grayia		
LUPIN	Lupinus	HALOG	Halogeton		
OENOT	Oenothera	JUNIP	Juniperus		
PURSH	Purshia	LEPTO2	Leptodactylon		
POTEN	Potentilla	MERTE	Mentensia		
PINUS	Pinus	OPUNT	Opuntia		
SARCO	Sarcobotus	PHLOX	Phlox		
SYMPH	Symphoricarpos	PURSH	Purshia		
	Unknown composite	PINUS	Pinus		
	Unknown forb	SAKA	Salsoa kali		
	Moss	SHEPH	Shepherdia		
			Unknown forb		
			Unknown seed		

(1) no comparison, based on Rock Springs average only

(2) based on Rawlins data only

Appendix Table III.10. (Continued)

SHEEP					
(1) SPRING & SUMMER		(1) FALL & WINTER		(1) YEARLY	
SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME
BROMU	Bromus	BOUTE	Bouteloua	CAREX	Carex
CAREX	Carex	BROMU	Bromus	ORHY	Oryzopsis hymenoides
FESTU	Festuca	FESTU	Festuca	POA++	Poa
KOELE	Koeleria	ORHY	Oryzopsis hymenoides	(FEOC2)	Vulpia octiflora
ORHY	Oryzopsis hymenoides	POA++	Poa	SPORO	Sporobolus
SPORO	Sporobolus	SITAN	Sitanion	DIST	Distichlis stricta
DIST	Distichlis stricta	MUHLE	Muhlenbergia	ARTEM	Artemisia
AMELA	Amelanchier	(FEOC2)	Vulpia octiflora	CHRYS9	Chrysothamnus
CEMO2	Cercocarpus montanus	SPORO	Sporobolus	EULAE2	Eurotia lanata
CHRYS9	Chrysothamnus	ARTEM	Artemisia	PURSH	Purshia
ERIGE2	Erigeron	CHRYS9	Chrysothamnus	SYMPH	Shymphoricarpos
ERIOG	Eriogonum	ERIOG	Eriogonum	SPHAE	Sphaeralcea
HALOG	Halogeton	GRSP	Grayia	SAKA	Salsoa kali
LEPTO2	Leptodactylon	LEPTO2	Leptodactylon		
LUPIN	Lupinus	OPUNT	Opuntia		
OPUNT	Opuntia	PHLOX	Phlox		
PURSH	Purshia	SARCO	Sarcobotus		
POTEN	Potentilla	SYMPH	Symphoricarpos		
SARCO	Sarcobotus	SPHAE	Sphaeralcea		
SPHAE	Sphaeralcea	SAKA	Salsoa kali		
	Unknown composite	VALER	Valeriana		
	Unknown forb				

Appendix Table III.10. (Continued)

BIGHORN SHEEP					
(2) SPRING & SUMMER		(2) FALL & WINTER		YEARLY	
SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME
ARIST	Aristida	BROMU	Bromus		
BROMU	Bromus	ELYMU	Elymus		
KOELE	Koeleria	KOELE	Koeleria		
ORHY	Oryzopsis hymenoides	ORHY	Oryzopsis hymenoides		
POA++	Poa	POA++	Poa		
SITAN	Sitanion	SITEN	Sitanion		
HESPE5	Hesperochloa	HESPE5	Hesperochloa		
ARTEM	Artemisia	ASTRA	Astragalus		
ASTRA	Astragalus	ATRIP	Atriplex		
ATRIP	Atriplex	BERBE	Berberis		
AMELA	Amelanchier	CEMO2	Cercocarpus montanus		
BERBE	Berberis	CHRYS9	Chrysothamnus		
CHRYS9	Chrysothamnus	CRYPT	Cryptantha		
CRYPT	Cryptantha	ERIGE2	Erigeron		
DESCU	Descurainia	ERIOG	Eriogonum		
ERIGE2	Erigeron	JUNIP	Juniperus		
ERIOG	Eriogonum	LEPTO2	Leptodactylon		
JUNIP	Juniperus	LESQU	Lesquerella		
LEPTO2	Leptodactylon	MELIL	Melilotus		
LESQU	Lesquerella	PURSH	Purshia		
MELIL	Melilotus	PINUS	Pinus		
PINUS	Pinus	PSEUD7	Pseudostuga		
PSEUD7	Pseudotsuga		Unknown forb		
SAKA	Salsoa kali		Unknown shrub		
	Unknown composite	ALLIU	Allium		
	Unknown seed				
	Atennaria				

Appendix Table III.10. (Continued)

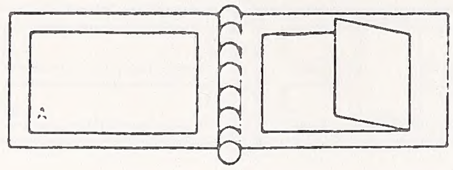
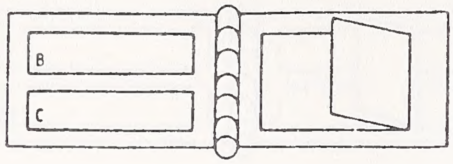
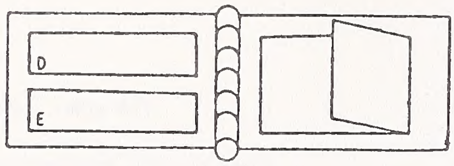
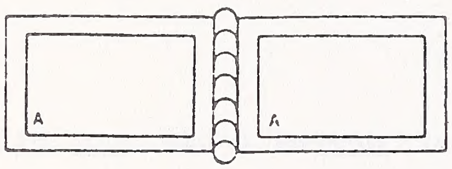
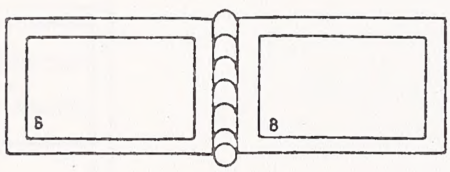
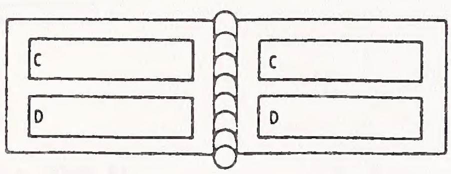
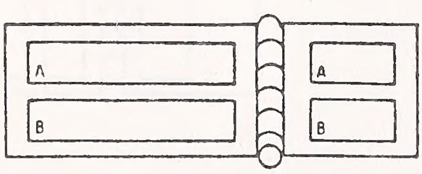
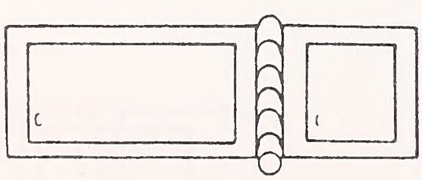
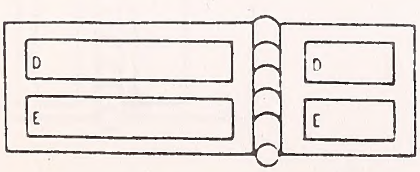
ANTELOPE					
SPRING & SUMMER		(1) FALL & WINTER		(1) YEARLY	
SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME	SCS PLANT CODE	SCIENTIFIC NAME
AGROP2	Agropyron	AGROP2	Agropyron	AGROP2	Agropyron
BROMU	Bromus	BROMU	Bromus	CAREX	Carex
CAREX	Carex	CAREX	Carex	ORHY	Oryzopsis hymenoides
KOELE	Koeleria	FESTU	Festuca	STIPA	Stipa
ORHY	Oryzopsis hymenoides	KOELE	Koeleria	ASTRA	Astragalus
POA++	Poa	ORHY	Oryzopsis hymenoides	CHRYS9	Chrysothamnus
SITAN	Sitanion	SITAN	Sitanion	CRYPT	Cryptantha
STIPA	Stipa	STIPA	Stipa	ELUA5	Eurotia lanata
ATRIP	Atriplex	ASTRA	Astragalus	ELAEA	Elaeagnus
BERBE	Berberis	ATRIP	Atriplex	PURSH	Purshia
CHRYS9	Chrysothamnus	DESCU	Descurainia		
CRYPT	Cryptantha	ERIOG	Eriogonum		
DELPH	Delphinium	EULA5	Eurotia lanata		
DESCU	Descurainia	LEPTO2	Leptodactylon		
ERIGE2	Erigeron	LESQU	Lesquerella		
GUTIE	Gutierrezia	LUPIN	Lupinus		
HALOG	Halogeton	MELIL	Melilotus		
JUNIP	Juniperus	OPUNT	Opuntia		
LEPTO2	Leptodactylon	OENOT	Oenothera		
LESQU	Lesquerella	PHLOX	Phlox		
LUPIN	Lupinus	PURSH	Purshia		
MELIL	Melilotus.	SYMPH	Symphoricarpos		
OPUNT	Opuntia				
OENOT	Oenothera				
PHLOX	Phlox				
PURSH	Purshia				
SARCO	Sarcobotus				
SYMPH	Symphoricarpos				
SPHAE	Sphaeralcea				
SAKA	Salsoa kali				
SHEPH	Shepherdia				
POTEN	Potentilla				
RHUS+	Rhus				
TETRA3	Tetradymia				
VALER	Valeriana				
YUCCA	Yucca				
ROSA+	Rosa				
	Unknown forb				
	Unknown seed				
	Moss				
	Unknown borage				

APPENDIX IV

Compilation of Botanical Composition of Diets of Large Herbivores

Footnotes

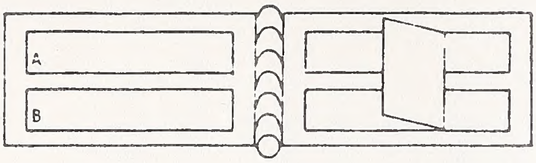
Appendix Figure IV.1. Presentation of the botanical composition of large herbivores of equal to or greater than 5 percent. Large pages measure 11x17 inches. Standard pages measure 8.5x11 inches.

ANIMAL SPECIES	PLANT SPECIES	NUMBER OF PAGES	PAPER SIZE
CATTLE - Table B1			
	A) GRASSES	(FIRST GROUP) 3pp.	3 LARGE
	B) GRASSES (CONT.) C) FORBS	(SECOND GROUP) OF 3pp.	3 LARGE
	D) SHRUBS E) OTHER	(THIRD GROUP) OF 3pp.	3 LARGE
SHEEP - Table B3			
	A) GRASSES	2pp.	2 LARGE
	B) FORBS	2pp.	2 LARGE
	C) SHRUBS D) OTHER	2pp.	2 LARGE
MULE DEER - Table B11			
	A) GRASSES B) FORBS	2pp.	1 LARGE AND 1 STANDARD
	C) SHRUBS	2pp.	1 LARGE AND 1 STANDARD
	D) SHRUBS (CONT.) E) OTHER	2pp.	1 LARGE AND 1 STANDARD

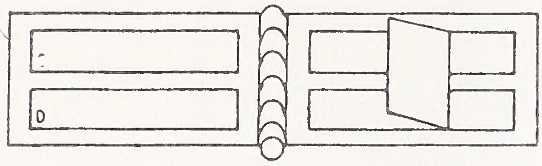
Appendix Figure IV.1 (Continued)

ANIMAL SPECIES	PLANT SPECIES	NUMBER OF PAGES	PAPER SIZE

PRONGHORN ANTELOPE - Table B9

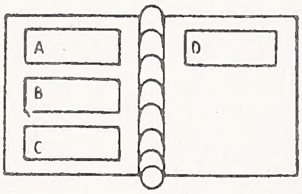


A) GRASSES B) FORBS	3pp.	3 LARGE



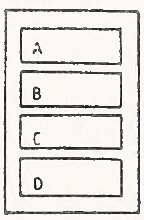
C) SHRUBS D) OTHER	3pp.	3 LARGE

WHITETAIL DEER - Table B13



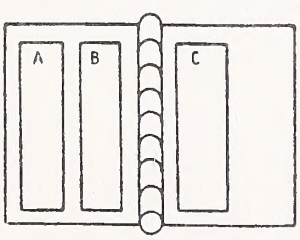
A) GRASSES B) FORBS C) SHRUBS D) OTHER	2pp.	2 STANDARD

BURRO - Table B19, BISON - Table B5, AND HORSES - Table B17



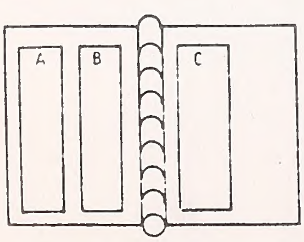
A) GRASSES B) FORBS C) SHRUBS D) OTHER	1pp. each	1 STANDARD

BIGHORN SHEEP - Table B7



A) GRASSES B) FORBS C) SHRUBS	2pp.	2 STANDARD

ELK - Table B15



A) GRASSES B) FORBS C) SHRUBS	2pp.	2 STANDARD

Appendix Figure IV.1 (Continued)

Appendix Table IV.1. Cattle, diet components with composition proportion of 5 percent or greater compiled from the scientific literature.

SCS Plant Code	Scientific Name	Photosynthetic Pathway	Ref. 2 BC	Warm Season	Cool Season	Ref. 5 OK	Summer	Ref. 10 FA	Annual	Ref. 12 CP	Summer	Winter	Ref. 13 FA	Summer	Ref. 16 FA	Summer	Ref. 17 FA	Warm Season	Ref. 19 FA	Spring/Summer	Fall/Winter	Ref. 20 RA
	TOTAL GRASSES										67	60										
BOGR2	Bouteloua gracilis	C_4		30	36		6				36	31						5		17	13	
BROMU2	Bromus sp.	C_3												6		7						
LYPH	Lycurus phleoides	C_4									10	6										
SIHI	Sitanion hystrix	C_3																				
AGSM	Agropyron smithii	C_3		9	15		75							17						22	32	
STCO4	Stipa comata	C_3		9	33		40							28		13					10	
FESTU	Festuca sp.	C_3																23				
CALO	Calamovilfa longifolia	C_4		30	9																	
ANHA	Andropogon hallii	C_4*		8																		
KOCR	Koeleria cristata	C_3					20							7		12						
POSE	Poa secunda	C_3					9															
TRIDE	Tridens sp.	C_4*							27													
EPNE	Ephedra nevadensis								15													
MUPO2	Muhlenbergia porteri	C_4							15													
CAREX	Carex sp.	C_3							5					30		31		23		33	13	
BRMA3	Bromus marginatus	C_3																				
BOCU	Bouteloua curtipendula	C_4									7	5										
BOER4	Bouteloua eriopoda	C_4																				
SPFL2	Sporobolus flexuosus	C_4																				
ARAD	Aristida adscensionis	C_4*																				
ARIST	Aristida sp.	C_4*										16										
AGROP2	Agropyron sp.	C_3														16						
POA++	Poa sp.	C_3														5		18				
DANTH	Danthonia sp.	C_3*																24				
BUDA	Buchloe dactyloides	C_4																				
ANSA*	Bothriochloa saccharoides	C_4																				
BOBA2	Bouteloua barbata	C_4																				
MURI	Muhlenbergia richardsonis	C_4*																				
SPCR	Sporobolus cryptandrus	C_4																		8	14	
STIPA	Stipa sp.	C_3																				
FEAR2	Festuca arizonica	C_3*																				
MUMO	Muhlenbergia montana	C_4*																				
PAPL3	Paspalum plicatulum	C_4																				
CYDA	Cynodon dactylon	C_4																				
SONU2	Sorghastrum nutans	C_4																				
ANSC2	Schizachyrium scoparium	C_4																				
PALI7	Paspalum lividum	C_4*																				
SPIN4	Sporobolus indicus	C_4																				
AGSP	Agropyron spicatum	C_3																				
FEID	Festuca idahoensis	C_3																				
BRRU2	Bromus rubens	C_3*																				
BRIN2	Bromus inermis	C_3																				
AICA	Aira caryophyllea																					
POPR	Poa pratensis	C_3																				
CANE2	Carex nebraskensis	C_3*																				
CAIN	Calamagrostis inexpansa	C_3*																				
AGTR	Agropyron trachycaulum	C_3*																				
POCU3	Poa cusickii	C_3																				
STTH2	Stipa thurberiana	C_3																				
ORHY	Oryzopsis hymenoides	C_3																				
STOC2	Stipa occidentalis	C_3*																				
CAHE5	Carex heliophila	C_3																				
ARLO3	Aristida longiseta	C_4																				
ARSTS	Aristida stricta	C_4*																				
SPCU	Sporobolus curtissii	C_4*																				
ANDRO2	Andropogon sp.	C_4																				
AXAF	Axonopus affinis	C_4																				
	Fingergrass																					
BRMO2	Bromus mollis	C_3*																				
AVBA	Avena barbata	C_3																				
ELCI2	Elymus cinereus	C_3																				
GAVE3	Gastridium ventricosum																					
BRRI	Bromus rigidus	C_3																				
FEME	Festuca megalura	C_3																				
HOLE	Hordeum leporinum	C_3*																				
ERLE2	Eragrostis lehmanniana	C_4																				
SEMAS	Setaria macrostachya	C_4*																				
TRICH	Trichachne californica	C_4*																				
PINIC	Panicum sp.																					

SCS Plant Code	Scientific Name	Summer	Ref. 21 ME	Summer	Winter	Ref. 23 RA	Summer	Ref. 24 EA	Dec.-April	Ref. 26 FA	1977-1978	Ref. 27 FA	Summer	Ref. 28 FA	Yearly	Ref. 29 WA	July August October	Ref. 30 EA	Light Grazing	Heavy Grazing	Ref. 41 BC
	TOTAL GRASSES			77	79		68						73								
BOGR2	Bouteloua gracilis	31		59	34														36	40	
BROMU2	Bromus sp.										6										
LYPH	Lycurus phleoides																				
SIHI	Sitanion hystrix																39				
AGSM	Agropyron smithii						15												7	7	
STCO4	Stipa comata																		6		
FESTU	Festuca sp.																				
CALO	Calamovilfa longifolia																				
ANHA	Andropogon hallii																				
KOCR	Koeleria cristata																				
POSE	Poa secunda																				
TRIDE	Tridens sp.																				
EPNE	Ephedra nevadensis																				
MUPO2	Muhlenbergia porteri																				
CAREX	Carex sp.																				
BRMA3	Bromus marginatus																				
BOCU	Bouteloua curtipendula																				
BOER4	Bouteloua eriopoda																				
SPFL2	Sporobolus flexuosus																				
ARAD	Aristida adscensionis																				
ARIST	Aristida sp.																				
AGROP2	Agropyron sp.														54						
POA++	Poa sp.										14										
DANTH	Danthonia sp.																				
BUDA	Buchloe dactyloides	12																			
ANSA*	Bothriochloa saccharoides	5																			
BOBA2	Bouteloua barbata																				
MURI	Muhlenbergia richardsonis				25																
SPCR	Sporobolus cryptandrus	11		13	7																
STIPA	Stipa sp.														11						
FEAR2	Festuca arizonica						7														
MUMO	Muhlenbergia montana						11														
PAPL3	Paspalum plicatulum								22												
CYDA	Cynodon dactylon								12												
SONU2	Sorghastrum nutans								5												
ANSC2	Schizachyrium scoparium								23												
PALI7	Paspalum lividum								14												
SPIN4	Sporobolus indicus								15												
AGSP	Agropyron spicatum										19		32								
FEID	Festuca idahoensis										5										
BRRU2	Bromus rubens																				
BRIN2	Bromus inermis																				
AICA	Aira caryophyllea																				
POPR	Poa pratensis																				
CANE2	Carex nebraskensis																				
CAIN	Calamagrostis inexpansa																				
AGTR	Agropyron trachycaulum																				
POCU3	Poa cusickii												25								
STTH2	Stipa thurberiana												12								
ORHY	Oryzopsis hymenoides														9						
STOC2	Stipa occidentalis																12				
CAHE5	Carex heliophila																		9	9	
ARLO3	Aristida longiseta																			6	
ARSTS	Aristida stricta																				
SPCU	Sporobolus curtissii																				
ANDRO2	Andropogon sp.																				
AXAF	Axonopus affinis																				
	Fingergrass																				
BRMO2	Bromus mollis																				
AVBA	Avena barbata																				
ELCI2	Elymus cinereus																				
GAVE3	Gastridium ventricosum																				
BRRI	Bromus rigidus																				
FEME	Festuca megalura																				
HOLE	Hordeum leporinum																				
ERLE2	Eragrostis lehmanniana																				
SEMAS	Setaria macrostachya																				
TRICH	Trichachne californica																				
PINIC	Panicum sp.																				

SCS Plant Code	Scientific Name	Heavy Grazing	Moderate Grazing	Light Grazing	No Other Use	Ref. 43 OE & CP	June	Sept.	Ref. 44 OE & CP	Fertilized	Unfertilized	Ref. 55 RA	Winter	Ref. 56 FA	Georgia USA	Ref. 60 CP & FA	CA 1969-70	FA 1969-70	Ref. 65 BC	Summer-Early Fall	SCS Plant Code
	TOTAL GRASSES	92	88	79	55		88	92		51	78				77		65	80		85	
BOGR2	Bouteloua gracilis																37	57		29	BOGR2
BROMU2	Bromus sp.																				BROMU2
LYPH	Lycurus phleoides																				LYPH
SIHI	Sitanion hystrix																				SIHI
AGSM	Agropyron smithii																8	8			AGSM
STCO4	Stipa comata																5				STCO4
FESTU	Festuca sp.																				FESTU
CALO	Calamovilfa longifolia																				CALO
ANHA	Andropogon hallii																				ANHA
KOCR	Koeleria cristata																				KOCR
POSE	Poa secunda																				POSE
TRIDE	Tridens sp.																				TRIDE
EPNE	Ephedra nevadensis																				EPNE
MUPO2	Muhlenbergia porteri																				MUPO2
CAREX	Carex sp.																				CAREX
BRMA3	Bromus marginatus																				BRMA3
BOCU	Bouteloua curtipendula																			16	BOCU
BOER4	Bouteloua eriopoda												6								BOER4
SPFL2	Sporobolus flexuosus																				SPFL2
ARAD	Aristida adscensionis																				ARAD
ARIST	Aristida sp.																				ARIST
AGROP2	Agropyron sp.																				AGROP2
POA++	Poa sp.																				POA++
DANTH	Danthonia sp.																				DANTH
BUDA	Buchloe dactyloides																				BUDA
ANSA*	Bothriochloa saccharoides																			8	ANSA*
BOBA2	Bouteloua barbata																				BOBA2
MURI	Muhlenbergia richardsonis																				MURI
SPCR	Sporobolus cryptandrus																			31	SPCR
STIPA	Stipa sp.																				STIPA
FEAR2	Festuca arizonica																				FEAR 2
MUMO	Muhlenbergia montana																				MUMO
PAPL3	Paspalum plicatulum																				PAPL3
CYDA	Cynodon dactylon																				CYDA
SONU2	Sorghastrum nutans																				SONU2
ANSC2	Schizachyrium scoparium																				ANSC2
PALI7	Paspalum lividum																				PALI7
SPIN4	Sporobolus indicus																				SPIN4
AGSP	Agropyron spicatum																				AGSP
FEID	Festuca idahoensis																				FEID
BRRU2	Bromus rubens										5										BRRU2
BRIN2	Bromus inermis																				BRIN2
AICA	Aira caryophyllea																				AICA
POPR	Poa pratensis																				POPR
CANE2	Carex nebraskensis																				CANE2
CAIN	Calamagrostis inexpansa																				CAIN
AGTR	Agropyron trachycaulum																				AGTR
POCU3	Poa cusickii																				POCU3
STTH2	Stipa thurberiana																				STTH2
ORHY	Oryzopsis hymenoides																				ORHY
STOC2	Stipa occidentalis																				STOC2
CAHE5	Carex heliophila																9	8			CAHE5
ARLO3	Aristida longiseta																5	7			ARLO3
ARSTS	Aristida stricta						5								11						ARSTS
SPCU	Sporobolus curtissii						5								9						SPCU
ANDRO2	Andropogon sp.						31	40							25						ANDRO2
AXAF	Axonopus affinis						19	20							5						AXAF
	Fingergrass							15													
BRMO2	Bromus mollis									14	31										BRMO2
AVBA	Avena barbata																				AVBA
ELCI2	Elymus cinereus																				ELCI2
GAVE3	Gastridium ventricosum																				GAVE3
BRRI	Bromus rigidus										6										BRRI
FEME	Festuca megalura									29	27										FEME
HOLE	Hordeum leporinum										6										HOLE
ERLE2	Eragrostis lehmanniana												23								ERLE2
SEMAS	Setaria macrostachya												36								SEMAS
TRICH	Trichachne californica												17								TRICH
PINIC	Panicum sp.														6						PINIC

SCS Plant Code	Ref. 66 FA	Summer	Ref. 70 CP, FA, & CE	Seeded 1967-68	Native 1967-68	Old Fields 1967-68	Ref. 71 RA	Winter Native Meadow	Fall Native Meadow Regrowth	Spring/Summer Seeded Range Native Bunchgrass	Fall Seeded Range Native Bunchgrass	Ref. 72 CA & RA	Summer	Ref. 73 RA	May-November 1960-66 Sagebrush Grass	Desert Shrub	Northern Desert Shrub	Ref. 74 CA & RA	Spring	Summer	Fall	Ref. 75 DF	May-October Native	May-October Seeded	May-October Old Field	Ref. 76 CA	Spring/Summer	Fall/Winter	Ref. 78 FA	June, July, Sept.	December	Ref. 80 CA	Summer	Ref. 81 RA	Sept.-December	Ref. 82 CA	Summer Sagebrush	Summer Aspen	Ref. 83 FA	Summer Sagebrush Grass	Summer Desert Shrub 1959	Fall October-December 1959	Spring/Summer April, May, June, August, Sept. 1960	Fall/Winter October, January, Feb., March 1960	Ref. 85 FA	Winter	Early/Late Summer	Ref. 86 OC	July-October	SCS Plant Code
								77	98	71	76				83	26	80										43	44									77	84		68	19	5	49	16		98	61		78	
BOCR2				15	50	6				7									21	38	22		55	37	16					33	28																			BOCR2
BROMU2		7											34																				54																	BROMU2
LYPH																																																		LYPH
SIHI																																														63	21			SIHI
AGSM										14	22								35	33	12																													AGSM
STCO4																			23	6	22									11	54																			STCO4
FESTU																																																		FESTU
CALO																			5	5	8									23																				CALO
ANHA																			6	15																														ANHA
KOCR																																																		KOCR
POSE																																																		POSE
TRIDE																																																		TRIDE
EPHE																																																		EPHE
HUPO2																																																		HUPO2
CAREX																																																		CAREX
BRHA3																																																	21	BRHA3
BOCU				56		6																		28	6																									BOCU
BOER4																											9	8							6															BOER4
SPFL2																											23	16																						SPFL2
ARAD																											9	17																						ARAD
ARIST																																																		ARIST
AGROP2		27																																																AGROP2
POA++																																																		POA++
DANTH																																																		DANTH
BUDA					14	15																	9	11	17																									BUDA
ANSA*																																																		ANSA*
BOBA2																																																		BOBA2
HURI																																																		HURI
SPCR				5	15	60														7	5		10	21	59																									SPCR
STIPA		50																																																STIPA
FEAR2										33																																								FEAR2
HUMO										13	34																																							HUMO
PAPL3																																																		PAPL3
CYDA																																																		CYDA
SONU2																																																		SONU2
ANSC2																																																		ANSC2
PALI7																																																		PALI7
SPIN4																																																		SPIN4
AGSP																																																		ACSP
FEID																																																	13	FEID
BRRU2																																																		BRRU2
BRIN2																																																		BRIN2
RICA																																	7																	RICA
POPR								16	42																																									POPR
CANE2								24	23																																									CANE2
CAIN								8	24																																									CAIN
AGTR								14																																									14	AGTR
POCU3																																																		POCU3
STTH2																																																		STTH2
ORHY																																														16	7			ORHY
STCO2																																																		STCO2
CAHES											32																																							CAHES
ARLO3																																																		ARLO3
ARSTS																																																		ARSTS
SPCU																																																		SPCU
ANDRO2																																																		ANDRO2
AXAF																																																		AXAF
BRDO3																																																		BRDO7
AVBA													5																				21																	AVBA
ELCI2																																														19				ELCI2
GAVE3													7																				73																	GAVE3
BRRI																																																		BRRI
FLME																																																		FLME
HOLE																																																		HOLE
ERLE2																																																		ERLE2
SEMAS																																			23															SEMAS
TRICH																																			36															TRICH
PINIC																																			17															PINIC

Nomenclature or authority change since time of publication

Provisional photosynthetic pathway assignment

SCS PLANT CODE	Ref. 87 OE	Spring/ Summer	Fall/ Winter	Ref. 92 CA	Summer	Winter	Ref. 93 CP	Aspen Forb	Aspen Browse	Oak	Ref. 99 OE	Fall	Winter	Spring	Summer	Ref. 100 CA	Summer Heavy Use	Summer Medium Use	Summer Light Use	Ref. 101 RA	Native Range	Ref. 102 OE	Summer	Early Fall	Ref. 103 OE	Year Long	Ref. 104 OE	Year Long	Ref. 105 RA	Yearly	SCS PLANT CODE
					58	73		86	76	8		50	58	47	77		65	54	51				67	85		61					
BOGR2		26	46														32	18	29					7				61		27	BOGR2
BROHU2																															BROHU2
LYPH																															LYPH
SIHI																															SIHI
AGSM																	7	15	8				24	21						14	AGSM
STCO4		22	24																				7	49							STCO4
FESTU																															FESTU
CALO																															EALO
ANHA			5																												ANHA
KOCR																															KOCR
POSE																															POSE
TRIDE																															TRIDE
EPHE																															EPHE
MUPO2																															MUPO2
CAREX																	14	7	8												CAREX
BRMA3																															BRMA3
BOCU																												11			BOCU
BOER4					7	62						6	23		5						6										BOER4
SPFL2					45	8						13	13	13	20																SPFL2
APAD																															ACAD
ARIST																	7	7													ARIST
AGROP2																															AGROP2
POA++																															POA++
DANTH																															DANTH
BUDA																															BUDA
ANSA*																															ANSA*
BOBA2													5																		BOBA2
MURI																															MURI
SPCR																												8			SPCR
STIPA																															STIPA
ELAR2																															ELAR2
MUMO																															MUMO
PAPL3																															PAPL3
CYDA																															CYDA
SONU2																															SONU2
ANST2																															ANST2
PALI7																															PALI7
SPIN4																															SPIN4
AGSP																															AGSP
TEID																							19	8							TEID
BRRU2																															BRRU2
BRER2																							10								BRER2
AITR																															AITR
POPR																															POPR
CANE2																															CANE2
CAIN																															CAIN
AGTR																															AGTR
POFU3																															POFU3
STTH2																															STTH2
ORHY																															ORHY
STCO2																															STCO2
CAHES																															CAHES
ARLO3														6	5																ARLO3
ARSI5																															ARSI5
SPCU																															SPCU
ANDRO2																															ANDRO2
AXAF																															AXAF
BRMO2																															BRMO2
AVBA																															AVBA
ELCI2																															ELCI2
GAVE3																															GAVE3
BRRI																															BRRI
FEME																															FEME
HOLE																															HOLE
CALE2																					23										CALE2
SEMAS					5																36										SEMAS
TRICH																					17										TRICH
PINIC																															PINIC

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 2 RC	Warm Season	Cool Season	Ref. 5 OE	Summer	Ref. 10 FA	Annual	Ref. 12 EA	Summer	Winter	Ref. 13 FA	Summer	Ref. 16 FA	Summer	Ref. 17 FA	Warm Season	Ref. 19 FA	Spring/ Summer	Fall/ Winter	Ref. 20 FA	Summer	Ref. 21 RC	Summer	Winter	Ref. 23 RA	Summer	Ref. 24 EA	Dec.-April	Ref. 26 FA	1977-1978	Ref. 27 FA	Summer	Ref. 28 FA	Yearly	Ref. 29 WA	July, August, October	Ref. 30 EA	Light Grazing	Heavy Grazing	Ref. 41 RC	Heavy Grazing	Moderate Grazing	Light Grazing	No Other Use	Ref. 43 OE & CP	June	Sept.	Ref. 44 OE & CP	Fertilized	Unfertilized	Ref. 55 AA	Winter	Ref. 56 CA	Georgia, USA	Ref. 60 CA & FA	EA 1969-72	FA 1969-70	Ref. 65 RC	Summer-Early Fall	SCS PLANT CODE
	GRASSES (cont.)																																																													
BOHI2	Bouteloua hirsuta	C_4																																																												BOHI2
STPU2	Stipa pulchra	C_3*																																																												STPU2
BRTE	Bromus tectorum	C_3																																																												BRTE
	Sandraad																																																													
HIMU2	Hilaria mutica	C_4																																																												HIMU2
SCBR2	Scleropogon brevifolius																																																													SCBR2
SPAI	Sporobolus airoides	C_4																																																												SPAI
CAEL2	Carex eleocharis	C_3																																																												CAEL2
	Unidentified grasses																										16		5																	28	16							12						

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 2 RC	Warm Season	Cool Season	Ref. 5 OE	Summer	Ref. 10 FA	Annual	Ref. 12 EA	Summer	Winter	Ref. 13 FA	Summer	Ref. 16 FA	Summer	Ref. 17 FA	Warm Season	Ref. 19 FA	Spring/ Summer	Fall/ Winter	Ref. 20 FA	Summer	Ref. 21 RC	Summer	Winter	Ref. 23 RA	Summer	Ref. 24 EA	Dec.-April	Ref. 26 FA	1977-1978	Ref. 27 FA	Summer	Ref. 28 FA	Yearly	Ref. 29 WA	July, August, October	Ref. 30 EA	Light Grazing	Heavy Grazing	Ref. 41 RC	Heavy Grazing	Moderate Grazing	Light Grazing	No Other Use	Ref. 43 OE & CP	June	Sept.	Ref. 44 OE & CP	Fertilized	Unfertilized	Ref. 55 AA	Winter	Ref. 56 CA	Georgia, USA	Ref. 60 CA & FA	EA 1969-72	FA 1969-70	Ref. 65 RC	Summer-Early Fall	SCS PLANT CODE
	TOTAL FORBS										31	34													17	24		31						26										6	13	14		10	8		49	44				6					15	
PSTE3	Psoralea tenuiflora	C_4																																						6																									PSTE3
ERAF	Eriogonum effusum	C_4*																																							7																				5			ERAF
SAKA	Salsola kali	C_4																																																												SAKA
SALSO	Salsola sp.	C_4																																																												SALSO
ARCA13	Artemisia carruthii										14	12														19																																								ARCA13
TRIFO	Trifolium sp.	C_3*																																																	46	10										TRIFO
POPE8	Potentilla pennsylvanica	C_4*																										8																																		POPE8
SISYM	Sisymbrium sp.	C_3*																																																												SISYM
SPHAE	Sphaeralcea sp.	C_4							5		[illegible]																																																					SPHAE
ASTRA	Astragalus sp.	C_3										8																																																		ASTRA
VERBE	Verbena sp.											7																																																		VERBE
GUSA2	Gutierrezia sarothrae	C_3										5																																																		GUSA2
HYGL2	Hypochaeris glabra																																																													HYGL2
MEHI	Medicago hispida	C_3*																																																												MEHI
POLYP	Polypodium sp.																																																													POLYP
ASTER	Aster sp.																																																													ASTER
CREP	Crepis sp.	C_3																																																												CREP1
DESCU	Descurainia sp.	C_3																																																												DESCU
	Dalea sp.																																																													
ERBO	Erodium botrys																																																													ERBO
LIFE	Lesquerella fendleri	C_3																																																												LIFE
PSTA	Psilostrophe tagetina	C_4																																																												PSTA
ARFR4	Artemisia frigida	C_3																										11																																		ARFR4
SPCO	Sphaeralcea coccinea	C_4																		9																				15	11																		9	7			SPCO
CRAT	Crepis atrabarba	C_3																																22																												CRAT
PORTU	Portulaca sp.	C_4																							14																																				PORTU
OECO2	Oenothera coronopifolia	C_4																																						6																									OECO2
CIUN	Cirsium undulatum	C_4																																																												CIUN
KOCH1	Kochia sp.	C_4																																																											10	KOCH1
KOSC	Kochia scoparia	C_4																					37																	5																									KOSC
MESA	Medicago sativa	C_3																																																												MESA
MEOF	Melilotus officinalis	C_3																																																												MEOF
CRCO11	Croton corymbulosus	C_4																																																												CRCO11
ERIOG	Eriogonum sp.																																																													ERIOG
OENOT	Oenothera sp.	C_4																																																												OENOT
	Unidentifiable forbs																											11																																		

SCS PLANT CODE	Ref. 66 FA	June-Sept.	Ref. 70 CP, FA, & CE	Seeded 1967-68	Native 1967-68	Old Fields 1967-68	Ref. 71 RA	Winter Native Meadow	Fall Native Meadow Regrowth	Spring/Summer Seeded Range Native Bunchgrass	Fall Seeded Range Native Bunchgrass	Ref. 72 EA & RA	Summer	Ref. 73 RA	May-November 1960-64 Sagebrush Grass	Desert Shrub	Northern Desert Shrub	Ref. 74 EA & RA	Spring	Summer	Fall	Ref. 75 OE	May-October Native	May-October Seeded	May-October Old Field	Ref. 76 EA	Spring/Summer	Fall/Winter	Ref. 78 EA	June, July, Sept.	December	Ref. 80 EA	Summer	Ref. 81 FA	Sept.-December	Ref. 82 EA	Summer Sagebrush	Summer Aspen	Ref. 83 FA	Summer Sagebrush Grass	Summer Desert Shrub 1959	Fall-October-December 1959	Spring/Summer April, May, June, August, Sept., 1960	Fall/Winter October, January, Feb., March, 1960	Ref. 85 FA	Winter	Early/Late Summer	Ref. 86 OE	July-October	SCS PLANT CODE
BOHI2																																																		BOHI2
STPU2																																	15																	STPU2
BRTE																																															25			BRTE
HIMU2																																																		HIMU2
SCBR2																																																		SCBR2
SPAI																																																		SPAI
CAEL2																																																		CAEL2
								6		16	7									6	6									24	14		11														5		30	

SCS PLANT CODE	Ref. 66 FA	June-Sept.	Ref. 70 CP, FA, & CE	Seeded 1967-68	Native 1967-68	Old Fields 1967-68	Ref. 71 RA	Winter Native Meadow	Fall Native Meadow Regrowth	Spring/Summer Seeded Range Native Bunchgrass	Fall Seeded Range Native Bunchgrass	Ref. 72 EA & RA	Summer	Ref. 73 RA	May-November 1960-64 Sagebrush Grass	Desert Shrub	Northern Desert Shrub	Ref. 74 EA & RA	Spring	Summer	Fall	Ref. 75 OE	May-October Native	May-October Seeded	May-October Old Field	Ref. 76 EA	Spring/Summer	Fall/Winter	Ref. 78 EA	June, July, Sept.	December	Ref. 80 EA	Summer	Ref. 81 FA	Sept.-December	Ref. 82 EA	Summer Sagebrush	Summer Aspen	Ref. 83 FA	Summer Sagebrush Grass	Summer Desert Shrub 1959	Fall-October-December 1959	Spring/Summer April, May, June, August, Sept., 1960	Fall/Winter October, January, Feb., March, 1960	Ref. 85 FA	Winter	Early/Late Summer	Ref. 86 OE	July-October	SCS PLANT CODE
								21		27	24				8		11										23	45		9							11	13		8							39		22	
PSTE3																																																		PSTE3
CREF																																																		CREF
SAKA																																															39			SAKA
SALSO																												18																						SALSO
ARCA13																																																		ARCA13
TRIFO													7																				13																	TRIFO
POPE8																																																		POPE8
SISYM																												7																						SISYM
SPHAE																																																		SPHAE
ASTRA																																																		ASTRA
VERBI																																																		VERBI
GUSA2																																																		GUSA2
HYGL2																																	9																	HYGL2
MEHI																																	5																	MEHI
POLYP																																	12																	POLYP
ASTER																																																	14	ASTER
CREPI																																								5										CREPI
DESCU																												8																						DESCU
LABO													5																				23																	LABO
LEFE																																																		LEFE
PSTA																																																		PSTA
ARFR4																																																		ARFR4
SPCO											11																																							SPCO
CRAT																																																		CRAT
PORTU																																																		PORTU
OECO2																																																		OECO2
CIUN																					5																													CIUN
KOCHI				18	14	9																																												KOCHI
KOSC																																																		KOSC
MESA																																																		MESA
MEOF																																																		MEOF
CHCO11																																																		CHCO11
ERIOG																																																		ERIOG
OEHOT																																																		OEHOT
								16		17	9										8												15																8	

SCS PLANT CODE	Ref. 87 DE	Spring/Summer	Fall/Winter	Ref. 92 EA	Summer	Winter	Ref. 93 CP	Aspen-forb	Aspen-browse	Oak	Ref. 99 DE	Fall	Winter	Spring	Summer	Ref. 100 EA	Summer Heavy Use	Summer Medium Use	Summer Light Use	Ref. 101 RA	Native Range	Ref. 102 DE	Summer	Early Fall	Ref. 103 DE	Year Long	Ref. 104 DE	Year Long	Ref. 105 RA	Yearly	SCS PLANT CODE
BOHI2																												9			BOHI2
STPU2																															STPU2
BRTE																															BRTE
		42	17																												
HIMU2															12																HIMU2
SCBR2																															SCBR2
												9	9		13																
SRAI														19	10																SRAI
CAEL2																														8	CAEL2
																					13							5			

SCS PLANT CODE	Ref. 87 DE	Spring/Summer	Fall/Winter	Ref. 92 EA	Summer	Winter	Ref. 93 CP	Aspen-forb	Aspen-browse	Oak	Ref. 99 DE	Fall	Winter	Spring	Summer	Ref. 100 EA	Summer Heavy Use	Summer Medium Use	Summer Light Use	Ref. 101 RA	Native Range	Ref. 102 DE	Summer	Early Fall	Ref. 103 DE	Year Long	Ref. 104 DE	Year Long	Ref. 105 RA	Yearly	SCS PLANT CODE
					40	27		12	10	73		42	23	35	16		31	39	48				26	6		36					
PSTE3																															PSTE3
EREF																															EREF
SAKA																															SAKA
SALSO																															SALSO
ARCA14																															ARCA14
TRIFO																															TRIFO
POPL8																															POPL8
SISYM																															SISYM
SPHAE																															SPHAE
ASTRA																															ASTRA
VERBE																															VERBE
GUSA2																															GUSA2
HYGL2																															HYGL2
MEHI																															MEHI
POLYP																															POLYP
ASTER																															ASTER
CREPI																															CREPI
DESCU																															DESCU
					14																										
EPBO																															EPBO
LEFE					7	21																									LEFE
PSTA																															PSTA
					12							6		14																	
AHTR4																															AHTR4
SPCO																	14	11	21											11	SPCO
CRAT																															CRAT
PORTU																															PORTU
OECO2																															OECO2
CIUN																															CIUN
KOCHI																															KOCHI
KOSC																		7													KOSC
HESA																							8								HESA
MEOF																															MEOF
																							7								
CRCO11												9		10	11																CRCO11
ERIOG																	7	5													ERIOG
OENOT																			8												OENOT
																							10	5							

+ Provisional photosynthetic pathway assignment

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 2 BC	Warm Season	Cool Season	Ref. 5 OE	Summer	Ref. 10 FA	Annual	Ref. 12 EA	Summer	Winter	Ref. 13 FA	Summer	Ref. 16 FA	Summer	Ref. 17 FA	Warm Season	Ref. 19 FA	Spring/Summer	Fall/Winter	Ref. 20 EA	Summer	Ref. 21 MC	Summer	Winter	Ref. 23 RA	Summer	Ref. 24 EA	Dec.-April	Ref. 26 FA	1977-1978	Ref. 27 FA	Summer	Ref. 28 FA	Yearly	Ref. 29 MA	July-August-October	Ref. 30 EA	Light Grazing	Heavy Grazing	Ref. 41 BC	Heavy Grazing	Moderate Grazing	Light Grazing	No Other Use	Ref. 43 OE & CA	June	Sept.	Ref. 44 OE & CA	Fertilized	Unfertilized	Ref. 55 RA	Winter	Ref. 56 FA	Georgia, USA	Ref. 60 EA & FA	EA 1969-70	FA 1969-70	Ref. 65 BC	Summer-Early Fall	SCS PLANT CODE
	TOTAL SHRUBS										7																																	7	14	31										17						
	Brigham tea																																																														
EULAS	Eurotia lanata																																		5																									EULAS
CORA	Coleogyne ramosissima																																																													CORA
PRJU	Prosopis juliflora								5																																																			PRJU
QUUN	Quercus undulata										7																																																	QUUN
YUEL	Yucca elata																																																												YUEL
PIPO	Pinus ponderosa																														6																													PIPO
ATRIP	Atriplex sp.	C_4																																	9																									ATRIP
PUTR2	Purshia tridentata																																				47																							PUTR2
QUERC	Quercus sp.																																																												QUERC
ARFI2	Artemesia filifolia																																																												ARFI2
EPNE	Ephedra nevadensis																																																												EPNE
SAAP2	Salvia aplana																																																												SAAP2
SYMPH	Symphocarpus sp.																																																												SYMPH
EPTR	Ephedra trifurcata																																																												EPTR
ARFR4	Artemisia frigida	C_3																																																										ARFR4
ACCO2	Acacia constricta								21																																																			ACCO2

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 2 BC	Warm Season	Cool Season	Ref. 5 OE	Summer	Ref. 10 FA	Annual	Ref. 12 EA	Summer	Winter	Ref. 13 FA	Summer	Ref. 16 FA	Summer	Ref. 17 FA	Warm Season	Ref. 19 FA	Spring/Summer	Fall/Winter	Ref. 20 EA	Summer	Ref. 21 MC	Summer	Winter	Ref. 23 RA	Summer	Ref. 24 EA	Dec.-April	Ref. 26 FA	1977-1978	Ref. 27 FA	Summer	Ref. 28 FA	Yearly	Ref. 29 MA	July-August-October	Ref. 30 EA	Light Grazing	Heavy Grazing	Ref. 41 BC	Heavy Grazing	Moderate Grazing	Light Grazing	No Other Use	Ref. 43 OE & CA	June	Sept.	Ref. 44 OE & CA	Fertilized	Unfertilized	Ref. 55 RA	Winter	Ref. 56 FA	Georgia, USA	Ref. 60 EA & FA	EA 1969-70	FA 1969-70	Ref. 65 BC	Summer-Early Fall	SCS PLANT CODE
	OTHER																																																														
	Unidentified																																																				13						

Appendix Table IV.1 (Continued)

SCS PLANT CODE	Ref. 66 FA	June-Sept.	Ref. 70 CP, FA, & OE	Seeded 1967-68	Native 1967-68	Old Field 1967-68	Ref. 71 RA	Winter Native Meadow	Fall Native Meadow Regrowth	Spring/Summer Seeded Range Native Bunchgrass	Fall Seeded Range Native Bunchgrass	Ref. 72 EA & RA	Summer	Ref. 73 RA	May-November 1960-66 Sagebrush Grass	Desert Shrub	Northern Desert Shrub	Ref. 74 EA & RA	Spring	Summer	Fall	Ref. 75 OE	May-October Native	May-October Seeded	May-October Old Field	Ref. 76 EA	Spring/Summer	Fall/Winter	Ref. 78 EA	June, July, Sept.	December	Ref. 80 EA	Summer	Ref. 81 RA	Sept.-December	Ref. 82 EA	Summer Sagebrush	Summer Aspen	Ref. 83 FA	Summer Sagebrush Grass	Summer Desert Shrub 1959	Fall October-December 1959	Spring/Summer April, May, June, August, Sept. 1960	Fall/Winter October, January, Feb., March 1960	Ref. 85 FA	Winter	Early/Late Summer	Ref. 86 OE	July-October	SCS PLANT CODE
															9	74	5										25	5									12			24	60	95	51	83						
																																												42						
EULAS																																									76	89								EULAS
CORA																																												9						CORA
PAJU																																																		PAJU
QUOM																																																		QUOM
YUEL																											26																							YUEL
PIPO																																																		PIPO
ATRIP																																											10							ATRIP
PUTR2																																								19										PUTR2
QUERC													7																				31																	QUERC
ARFI2																					5																													ARFI2
EPNE																																										6								EPNE
SAAP2																																											34	22						SAAP2
SYMPH																																																		SYMPH
EPTR																																																		EPTR
ARFR4																																																		ARFR4
ACCO2																																																		ACCO2

SCS PLANT CODE	Ref. 66 FA	June-Sept.	Ref. 70 CP, FA, & OE	Seeded 1967-68	Native 1967-68	Old Field 1967-68	Ref. 71 RA	Winter Native Meadow	Fall Native Meadow Regrowth	Spring/Summer Seeded Range Native Bunchgrass	Fall Seeded Range Native Bunchgrass	Ref. 72 EA & RA	Summer	Ref. 73 RA	May-November 1960-66 Sagebrush Grass	Desert Shrub	Northern Desert Shrub	Ref. 74 EA & RA	Spring	Summer	Fall	Ref. 75 OE	May-October Native	May-October Seeded	May-October Old Field	Ref. 76 EA	Spring/Summer	Fall/Winter	Ref. 78 EA	June, July, Sept.	December	Ref. 80 EA	Summer	Ref. 81 RA	Sept.-December	Ref. 82 EA	Summer Sagebrush	Summer Aspen	Ref. 83 FA	Summer Sagebrush Grass	Summer Desert Shrub 1959	Fall October-December 1959	Spring/Summer April, May, June, August, Sept. 1960	Fall/Winter October, January, Feb., March 1960	Ref. 85 FA	Winter	Early/Late Summer	Ref. 86 OE	July-October	SCS PLANT CODE
																											6	7					21		13								6	5						

SCS PLANT CODE	Ref. 87 OE	Spring/Summer	Fall/Winter	Ref. 92 EA	Summer	Winter	Ref. 93 CP	Aspen-forb	Aspen-browse	Oak	Ref. 99 OE	Fall	Winter	Spring	Summer	Ref. 100 EA	Summer Heavy Use	Summer Medium Use	Summer Light Use	Ref. 101 RA	Native Range	Ref. 102 OE	Summer	Early Fall	Ref. 103 OE	Year Long	Ref. 104 OE	Year Long	Ref. 105 RA	Yearly	SCS PLANT CODE
									14	19		8	19	18					8				7	11							
EULAS																															EULAS
CORA																															CORA
PRJU																															PRJU
QUUN																								9							QUUN
YUEL													17	16																	YUEL
PIPO																															PIPO
ATRIP																															ATRIP
PUTR2																															PUTR2
QUERC																															QUERC
ARFI2																															ARFI2
EPNE																															EPNE
SAAP2																															SAAP2
SYMPH																															SYMPH
EPTR													5																		EPTR
ARFR4																														13	ARFR4
ACCO2																															ACCO2

SCS PLANT CODE	Ref. 87 OE	Spring/Summer	Fall/Winter	Ref. 92 EA	Summer	Winter	Ref. 93 CP	Aspen-forb	Aspen-browse	Oak	Ref. 99 OE	Fall	Winter	Spring	Summer	Ref. 100 EA	Summer Heavy Use	Summer Medium Use	Summer Light Use	Ref. 101 RA	Native Range	Ref. 102 OE	Summer	Early Fall	Ref. 103 OE	Year Long	Ref. 104 OE	Year Long	Ref. 105 RA	Yearly	SCS PLANT CODE

Appendix Table IV.2. Cattle, additional diet components with composition proportion of less than 5 percent compiled from the scientific literature.

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
C- 10		BRRU2	Bromus rubens
		HIRI	Hilaria rigida
		STSP3	Stipa speciosa
		KRPA	Krameria parvifolia
		AGPA3	Agave palmeri
		OPUNT	Opuntia sp.
		YUNE2	Yucca newberryi
		TIOB	Tidestromia oblongifolia
		PHCOI5	Phragmites communis
			Seed
		ASTRA	Astragalus sp.
		OXYTR	Oxytropis sp.
			Lichen
C- 12	Spring/Summer	ARIST	Aristida sp.
		ARCAI4	Artemisia carruthi
		PAHA	Panicum hallii
		GUSA2	Gutierrezia sarothrae
		SIHY	Sitanion hystrix
		QUUN	Quercus undulata
		PEPA2	Pectis papposa
		MUTO2	Muhlenbergia torreyi
	Fall/Winter	BOCU	Bouteloua curtipendula
		GUSA2	Gutierrezia sarothrae
		SPCO	Sphaeralcea coccinea
		PAHA	Panicum hallii
		PEPA2	Pectis papposa
		BEHA	Berberis haematocarpa
		ATCA2	Atriplex canescens
		SIHY	Sitanion hystrix
		MUTO2	Muhlenbergia torreyl
		LEGO	Lesquerella gordonii
C- 13		EULA5	Eurotia lanata
		ORHY	Oryzopsis hymenoides
		CERCO	Cercocarpus sp.
		DANTH	Danthonia sp.
		AMUT	Amelanchier utahensis
		ARTR2	Artemisia tridentata
C- 16		ORHY	Oryzopsis hymenoides
		EULA5	Eurotia lanata
		FESTU	Festuca sp.
		AMUT	Amelanchier utahensis
		LESQU	Lesquerella sp.
		CHRYS9	Chrysothamnus sp.
		PIED	Pinus edulis
		BERBE	Berberis sp.
		SYMPH	Symphoricarpos sp.
		MERTE	Mertensia sp.
		JUNIP	Juniperus sp.
		CEMO2	Cercocarpus montanus
C- 19	Spring/Summer	STCO4	Stipa comata
		BUDA	Buchloe dactyloides
	Fall/Winter	SPCO	Sphaeralcea coccinea
		BUDA	Buchloe dactyloides
C- 20			Others (Unidentified)
C- 21	Summer	SPAN3	Sphaeralcea augustifolia
		SPCO	Sphaeralcea coccinea
	Winter	SPAN3	Sphaeralcea augustifolia
		SPCO	Sphaeralcea coccinea
		VERBE	Verbena sp.

Appendix Table IV.2. (Continued)

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
C- 22		DANTH	Danthonia sp.
		FESTU	Festuca sp.
		CAREX	Carex sp.
		ELYMU	Elymus sp.
		EULA5	Eurotia lanata
		CERCO	Cercocarpus sp.
		KOCR	Koeleria cristata
		ARTR2	Artemisia tridentata
		PUTR2	Purshia tridentata
		PIED	Pinus edulis
		AMUT	Amelanchier utahensis
C- 23		AGSM	Agropyron smithii
		BLTR	Blepharoneuron tricholepis
		BOGR2	Bouteloua gracilis
		CAIN	Calamagrostis inexpansia
		CAHE5	Carex heliophila
		DAPA2	Danthonia parryi
		POPR	Poa pratensis
		STCO4	Stipa comata
		STRO3	Stipa robusta
		ARFE3	Arenaria fendlerl
		CHAL7	Chenopodium album
		ERFL	Erigeron flagellaris
		GEPA2	Geranium parryi
		MEOF	Melilotus officinalis
		POAV	Polygonum aviculare
		CHVI8	Chrysothamnus viscidiflorus
C- 24		ROBR	Rosa bracteata
C- 27		FESTU	Festuca sp.
		DESCU	Descurainia sp.
		PHLOX	Phlox sp.
		ERIGE2	Erigeron sp.
		POSE	Poa secunda
		LUPIN	Lupinus sp.
C- 28	Annual Average	CAREX	Carex sp.
		*FESTU	Vulpia sp.
		ARTEM	Artemisia sp.
		SAVE4	Sarcobatus vermiculatus
		POA++	Poa sp.
		CRYPT	Cryptantha sp.
		DIST	Distichlis stricta
		PUTR2	Purshia tridentata
		ASTRA	Astragalus sp.
		OXYTR	Oxytropis sp.
		SYMPH	Symphoricarpos sp.
		LESQU	Lesquerella sp.
		CHNA2	Chrysothamnus nauseosus
C- 29	July, August, October		Least Lupine
		CARO5	Carex rossii
			Pink microseris
			Nodding microseris
C- 30	Light Stocking	KOSC	Kochia scoparia
		EREF	Erigonum effusum
		ARLO3	Aristida longiseta
		BUDA	Buchloe dactyloides
		ARFR4	Artemisia frigida
			Forbs
			Shrubs
			Grasses and Grasslike
	Heavy Stocking	OECO2	Oenothera coronopifolia
		STCO4	Stipa comata
		PSTE3	Psoralea tenuiflora
		KOSC	Kochia scoparia
		BUDA	Buchloe dactyloides
		ARFR4	Artemisia frigida
			Grasses and Grasslike

Appendix Table IV.2. (Continued)

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
C- 44	Unfertilized	BRAR3	Bromus arenarius
		BRRU2	Bromus rubens
		TRIFO	Trifolium sp.
		ERBO	Erodium botrys
	Fertilized	BRAR3	Bromus arenarius
		BRRU2	Bromus rubens
		BRRI	Bromus rigidus
		HOLE	Hordeum leporinum
		TRIFO	Trifolium sp.
		ERBO	Erodium botrys
C- 60	Esophageal	ARFR4	Artemisia frigida
		CIUN	Cirsium undulatum
		EREF	Eriogonum effusum
		BUOA	Buchloe dactyloides
		OECO2	Oenothera coronopifolia
		PSTE3	Psoralea tenuiflora
		SPCR	Sporobolus cryptandrus
		ASTRA	Astragalus sp.
		KOSC	Kochia scoparia
		EROI4	Erigeron divergens
	Fecal	KOSC	Kochia scoparia
		OECO2	Oenothera coronopifolia
		ARFR4	Artemisia frigida
		CIUN	Cirsium undulatum
		SPCR	Sporobolus cryptandrus
		STCO4	Stipa comata
		BUOA	Buchloe dactyloides
		ASTRA	Astragalus sp.
		PSTE3	Psoralea tenuiflora
		EROI4	Erigeron divergens
C- 65	May-October	CHAL7	Chenopodium album
C- 66	June-September	MUHLE	Muhlenbergia sp.
		CEMO2	Cercocarpus montanus
		STIPA	Stipa sp.
		AGROP2	Agropyron sp.
		LESQU	Lesquerella sp.
		CHRYS9	Chrysothamnus sp.
		ARIST	Aristida sp.
		PIEO	Pinus edulus
		ERIGE2	Erigeron sp.
		SHEPH	Shepherdia sp.
C- 70	Seeded	BUOA	Buchloe dactyloides
		CHAL7	Chenopodium album
	Native	BOCU	Bouteloua curtipendula
		CHAL7	Chenopodium album
	Old Field	CHAL7	Chenopodium album
C- 71	Native Meadow Winter Range	CHAL7	Chenopodium album
		JUBA	Juncus balticus
		MUMO	Muhlenbergia montana
		ARFR2	Artemesia frigida
		AGSC5	Agrostis scabra
		FEAR2	Festuca arizonica
		BOGR2	Bouteloua gracilis
		ARFE3	Arenaria fendleri
		GLST	Glyceria striata
		PHPR3	Phleum pratense
	Fall, Hay Meadow Regrowth	PHPR3	Phleum pratense
		AGSM	Agropyron smithii
		TRPR2	Trifolium pratense

Appendix Table IV.2. (Continued)

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
	Spring/Summer, Native Bunch-grass Range	KOCR	Koeleria cristata
		POPR	Poa pratensis
		STCO4	Stipa comata
		CAHE5	Carex heliophila
		POAV	Polygonium aviculare
		ARFE3	Arenaria fendleri
		DAPA2	Danthonia parryi
		STRO3	Stipa robusta
		MEOF	Meliotus officinalis
		BLTR	Blepharoneuron tricholepsis
		CHVI8	Chrysothamnus viscidifloris
			Astragalus striatus
		GEPA2	Geranium parryi
	Fall, Native Bunchgrass	CAIN	Calamagrostis inexpansa
		KOCR	Koeleria cristata
		BOGR2	Bouteloua gracilis
		FEAR2	Festuca arizonica
		POPE8	Potentilla pennsylvanica
			Astragalus striatus
		STCO4	Stipa comata
		ERFL	Erigeron flagellaris
C- 72	Summer	STPU2	Stipa pulchra
		CYDA	Cynodon dactylon
		AICA	Aira carophyllea
			Gassium parisiense
C- 74	Spring	KOSC	Kochia scoparis
		ARFI2	Artemesia filifolia
		SPCR	Sporobolus cryptandrus
		SPCO	Sphaeralcea ciccinea
		CHAL7	Chenopodium album
		SAKA	Salsola kali
	Summer	ARFI2	Artemisia filifolia
		SAKA	Salsola kali
		SPCO	Sphaeralcea coccinea
		CHAL7	Chenopodium album
	Fall	SAKA	Salsola kali
		CHAL7	Chenopodium album
		SPCO	Spaeralcea coccina
		ANHA	Andropogon hallii
C- 75	Seeded	KOCHI	Kochia sp.
		AGSM	Agropyron smithii
	Old Field	KOCHI	Kochia sp.
C- 76	Spring/Summer	ARIST	Aristida sp.
		LEFE	Lesquerella fendleri
		CHENO	Chenopodium sp.
		HYPO	Hymenopappus robustus
		CRCO11	Croton corymbulosus
		LELA	Lepidum lasiocarpum
		PORTU	Portulaca sp.
		SAKA	Salsola kali
		DIWI	Dithyrea wislizenii
		PSTA	Psilostrophe tagetina
		EPTO	Ephedra torreyana
	Fall/Winter	ARIST	Aristida sp.
		CRCR3	Cryptantha crassisepala
		PEWR3	Perezia wrightii
		CHENO	Chenopodium sp.
		CRCO11	Croton corymbulosus
		DIWI	Dithyrea wislizenii
		YUEL	Yucca elata
		EPTO	Ephedra torreyana
C- 78	December		Prairie sand reed
			Unidentified forbs

Appendix Table IV.2. (Continued)

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
C- 80	Summer	CYDA	Cynodon dactylon
		DAPU3	Daucus pusillus
		CARDU	Carduus sp.
		ORTHO	Orthocarpus sp.
		MADIA	Madia sp.
		LICI	Linanthus ciliatus
		GAPA5	Galium parisiense
		LUBI	Lupinus bicolor
		PLAGI	Plagiobothrys sp.
		SIGA	Silene gallica
		TONO	Torillis nodosa
		HORDE	Hordeum sp.
		MICA	Micropus californicus
		CIRSI	Cirsium sp.
		CYEC	Cynosurus echinatus
		VERAT	Veratrum sp.
		GODET	Godetia sp.
		LOMU	Lolium multiflorum
		NAVAR	Navarretia sp.
		GITR2	Gilia tricolor
		BRMI2	Briza minor
			Spanish moss
		ACHYR	Achyrachaena mollis
		CERAS	Cerastium sp.
		JUNCU	Juncus sp.
		ANAR	Anagallis arvensis
		ELCA5	Elymus caput-medusae
C- 81	September-December	CAER	Calliandra eriophylla
		OPEN2	Opuntia engelmannii
C- 83	Summer (Sage-brush-Grass)	JUNCU	Juncus sp.
		BASA3	Balsamorhiza sagittata
		SYRO	Symphoricarpos rotundifolia
		ATRIP	Atriplex sp.
		ARTR2	Artemisia tridentata
	Summer (Desert Shrub)	EPNE	Ephedra nevadensis
		ATRIP	Atriplex sp.
	Spring/Summer (1960)		Brigham tea
		CORA	Coleogyne ramosissima
	Fall/Winter (1960)	ATRIP	Atriplex sp.
C- 85	Summer	ELCI2	Elymus cinereus
	Winter	ERIOG	Eriogonum sp.
C- 87	Spring/Summer	ANHA	Andropogon hallii
			Sun sedge
		AGSM	Agropyron smithii
		SPCR	Sporobolus cryptandrus
			Summer cypress
		ARFI2	Artemisia filifolia
		AMBRO	Ambrosia sp.
		SALSO	Salsola sp.
		ARGL9	Cudweed sagewort
		IPLE	Ipomoea leptophylla
		YUCCA	Yucca sp.
		PHYSA	Physalis sp.
			Rushpea sp.
			Puccoon sp.
		HAPLO2	Haplopappus sp.
			Blackdot legume
	Fall/Winter	ARFI2	Artemisia filifolia
		SPCR	Sporobolus cryptandrus
		YUCCA	Yucca sp.
		AGSM	Agropyron smithii
		AMBRO	Ambrosia sp.
			Sun sedge
		SALSO	Salsola sp.
		HELIA3	Helianthus sp.

Appendix Table IV.2. (Continued)

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
C- 92	Summer		Erioneuron puchellum
		ARLO3	Aristida longiseta
		APRA	Aphanostephus ramosissimus
		GAILL	Gaillardia sp.
		HODE	Hoffmananseggia densiflora
		SAKA	Salsola kali
		SOEL	Solanum eleagnifolium
		DIWI	Dithyrea wislizeni
		SELO	Senecio longilobus
		CABA6	Cassia bauhinoides
		PSTA	Psilostrophe tagetinae
		PRJU	Prosopsis juliflora
		YUEL	Yucca elata
	Winter		Erioneuron puchellum
		SEMA5	Setaria macrostachya
		ARLO3	Aristida longiseta
		DALEA	Dalea sp.
		SAKA	Salsola kali
		SOEL	Solanum eleagnifolium
		DIWI	Dithyrea wislizeni
		SELO	Senecio longilobus
		PSTA	Psilostrophe tagetinae
C- 99	Fall	ARLO3	Aristida longiseta
		HIMU2	Hilaria muttica
		MUAR	Muhlenbergia arenacea
		MUPO2	Muhlenbergia porteri
		PAHA	Panicum hallii
		PAOB	Panicum obtusum
		SPAI	Sporobolus airoides
		TRPU2	Tridens pulchellus
		BOBA2	Bouteloua barbata
		MUSQ	Munroa squarrosa
		ALIN	Allionia incarnata
		BAAB	Bahia absinthifolia
		BAMU	Baileya multiradiata
		CIOC2	Cirsium ochrocentrum
		ERCA14	Erysimum capitatum
		LEFE	Lesquerella fendleri
		MELE2	Melampodium leucanthus
		PENA	Perezia nana
		SOEL	Solanum elaegnifolium
		SPSU	Sphaeralcea subhastata
		ZIGR	Zinnia grandiflora
		CONI3	Corispermum nitidum
		DIWI	Dithyrea wislizeni
			Guitierrezia sphaerocephala
		HODE	Hoffmannseggia densiflora
		TRTE	Tribulus terrestris
		ATCA2	Atriplex canescens
			Flourensia cernua
		GUSA2	Guitierrezia sarothrae
		YUEL	Yucca elata
	Winter	ARLO3	Aristida longiseta
		BOCU	Bouteloua curtipendula
		HIMU2	Hilaria muttica
		MUAR	Muhlenbergia arenacea
		PAHA	Panicum hallii
		PAOB	Panicum obtusum
		SPAI	Sporobolus airoides
		TRPU2	Tridens pulchellus
		BAAB	Bahia absinthlfolia
		CRCO11	Croton corymbulosus
		LEFE	Lesquerella fendlerl
		PENA	Perezia nana
		PSTA	Psilostrophe tagetinae
		SPSU	Sphaeralcea subhastata
		ZIGR	Zinnia grandlflora
			Descurainia menziesl

Appendix Table IV.2. (Continued)

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
		DIWI	Dithyrea wislizeni
		IVDE	Iva dealbata
		MEAL6	Mentzelia albicaulis
		SAKA	Salsola kali
		EPTR	Ephedra trifurca
			Flourensia cernua
		GUSA2	Guitierrezia sarothrae
		PRJU	Prosopsis juliflora
	Spring	BOER4	Bouteloua eriopoda
		HIMU2	Hilaria muttica
			Sporobolus brevifolius
		TRPU2	Tridens pulchellus
		BAAB	Bahia absinthifolia
		CHCO	Chamaesaracha coniodes
		LEFE	Lesquerella fendleri
		MELE2	Melampodium leucanthum
		SPSU	Shpaeralcea subhastata
		APRA	Aphanostephus ramossissimus
		CRCR3	Cryptantha crassisepala
			Descurainia menziesi
		DIWI	Dithyrea wislizeni
		IVDE	Iva dealbata
		MEAL6	Mentzella albicaulis
		NAHI	Nama hispidum
		PHIN2	Phacelia intermedia
		SAKA	Salsola kali
		ATCA2	Atriplex canescens
		GUSA2	Guitierrezia sarothrae
	Summer	MUAR	Muhlenbergia arenacea
		PAOB	Panicum obtusum
		TRPU2	Tridens pulchellus
		BOAR	Bouteloua aristoides
		BOBA2	Bouteloua barbata
		ALIN	Allionia incarnata
		BAMU	Baileya multiradiata
		MELE3	Melampodium leucanthus
		PSTA	Psilotrophe tangetinae
		SPHA	Sphaeralcea subhastata
		ZIGR	Zinnia grandiflora
		APRA	Aphanostephus ramosslssimus
		IVDE	Iva dealbata
		SAKA	Salsola kali
		ATCA2	Atriplex canescens
		EPTR	Ephedra trifurcata
			Flourensia cernua
		PRJU	Prosopsis juliflora
		YUEL	Yucca elata
C-100	Heavy Use	BUDA	Buchloe dactyloides
		KOSC	Kochia scoparia
		OENOT	Oenothera sp.
	Medium Use	BUDA	Buchloe dactyloides
		OENOT	Oenothera sp.
	Light Use	BUDA	Buchloe dactyloides
		ARIST	Aristida sp.
		ERIOG	Eriogonum sp.
		KOSC	Kochia scoparia
C-101		PRJUV	Prosopsis juliflora var. velutina
		CAER	Calliandra eriophylla
		OPEN2	Opuntia englemannii
C-102	Summer	BOGR2	Bouteloua gracilis
		STRI2	Stipa richardsoni
		GLLE	Glycyrrhiza lepidota
		PRVI	Prunus virginiana
		SYMPH	Symphoricarpos sp.
	Early Fall	GLLE3	Glycyrrhiza lepidota
		PRVI	Prunus virginiana

Appendix Table IV.2. (Continued)

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
C-104		HIJA	Hilaria jamesii
		PAOB	Panicum obtusum
		ARIST	Aristida sp.
		MURI	Muhlenbergia richardsonis
		MUTO2	Muhlenbergia torreyi
C-105		ARLO3	Aristida longiseta
		BUDA	Buchloe dactyloides
		MUTO2	Muhlenbergia torreyi
		SCPA	Schedonnardus paniculatus
		SPCR	Sporobolus cryptandrus
		AGCR	Agropyron cristatum
		BRTE	Bromus tectorum
		CAFI	Carex filifolia
		FEOC2	Festuca octoflora
		ORHY	Oryzopsis hymenoides
		SIHY	Sitanion hystrix
		STCO4	Stipa comata
		AMRE	Amaranthus retroflexus
		CHLE4	Chenopodium leptophyllum
		CIUN	Cirsium undulatum
		CLSE	Cleome serrulata
		COCA5	Conyza canadensis
		ERDI4	Erigeron divergens
		ERIGE2	Erigeron sp.
		EVNU	Evolvulus nuttallianus
		GACO5	Gaura coccinea
			Heterotheca villosa
		KOSC	Kochia scoparia
		LIPU	Liatris punctata
		MELIL	Melilotus sp.
		MILI3	Mirabilis linearis
		OEAL	Oenothera albiculis
		OECO2	Oenothera coronopifolia
		PSTE3	Psoralea tenuiflora
		RACO3	Ratibida columnifera
		SAKA	Salsola kali
		SOSE4	Sophora serica
		STPA4	Stephanomeria pauciflora
		THME	Thelesperma megapotamicum
		VEBR	Verbena bracteata
		ALTE	Allium textile
		*MATA2	Aster tanacetifolius
		ASTRA	Astragalus sp.
		BAOP	Bahia oppositifolia
		CRYPT	Cryptantha sp.
		CYMO	Cymopterus montanus
		DEPI	Descurainia pinnata
		ERBE2	Erigeron bellidiastrum
		LARE	Lappula redowski
		LEDE	Lepidium densiflorum
		LELU	Lesquerella ludoviciana
		LIIN2	Lithospermum incisum
		LUPU	Lupinus pusillus
		OXLA3	Oxytropis lambertii
		*PLPAG	Plantago purshii
		TOGR	Townsendia grandiflora
		ARFI	Artemisia filifolia
		ATCA2	Atriplex canescens
		CHNA2	Chrysothamnus nauseosus
		EREF	Eriogonum effusum
		GUSA2	Guitierriza sarothrae
		YUGL	Yucca glauca
		OPPO	Opuntia polyacantha
			Parmelia chlorochroa

*Nomenclature or authority change since time of publication

Appendix Table IV-2. (Continued)

Appendix Table IV.3. Sheep, diet components with composition proportion of 5 percent or greater compiled from the scientific literature.

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 7 EA	Summer July - August 1966-67	Early Summer	Mid Summer	Late Summer	Ref. 8 EA	Average 1966-67 Carter Mountain (Free grazing)	Average 1966-67 Morteese Creek (Herded)	Early July to Mid Sept	Ref. 12 EA	Summer	Winter	Ref. 28 FA	Yearly	Ref. 40 FA	Winter Range	Ref. 41 BC	Heavy grazing	Moderate grazing	Light grazing	No other use	Ref. 46 FA & EA	Location 1 - Good	Location 1 - Poor	Location 2 - Good	Location 2 - Poor	Ref. 47 CP	1946-48	Ref. 49 EA	Winter	July	Ref. 57 OC	Summer Range	Spring Range	Ref. 58 RA	April - Sept.	Oct. - March	Year	Ref. 59 EA	Spring	SCS PLANT CODE
	TOTAL GRASSES			24	30	23	20		44	32	32		42	31				50		79	62	6[illegible]	29		79	46	39	58		25		50			23	37		79	90	85		30	
CAEL3	Carex alynoides	C_3+							8	6	7																																CAEL3
FEOV	Festuca ovina	C_3+							}14	}12	}13																																FEOV
FERU2	Festuca rubina	C_3																																									FERU2
KOCR	Koeleria cristata	C_3																																									KOCR
BOGR2	Bouteloua gracilis	C_4											22	21																													BOGR2
ARIST	Aristida sp.	C_4+											9																														ARIST
AGROP2	Agropyron sp.	C_3+														14																											ACROP2
STIPA	Stipa sp.	C_3+														22																											STIPA
ORHY	Oryzopsis hymenoides	C_3																							17	23	12	7		8													ORHY
HIJR	Hilaria jamesii	C_4+																							29	22	15	46															HIJA
STCO4	Stipa comata	C_3																							48		12																STCO4
SPCR	Sporobolus cryptandrus	C_4																												6													SPCR
AGSP	Agropyron spicatum	C_3																																								8	ACSP
STLE4	Stipa lettermani	C_3+																																	5								STLE4
ACCR	Agropyron cristatum	C_3+																																		5							AGCR
	Gramineace (Green grass)																																					54	6[illegible]	56			
	Gramineace (Dry grass)																																					18	28	25			
POA++	Poa sp.	C_3																																								19	POA++
AGSM	Agropyron smithii	C_3																																									AGSM
POSE	Poa secunda	C_3																																									POSE
POFE	Poa fendleriana	C_3+																																	10	25							POFE
BROMU	Bromus sp.	C_3+																																									BROMU
GAVE3	Gastridium ventricosum																																										GAVE3
AGDA	Agropyron dasystachyum	C_3+																																									AGDA
BRIN2	Bromus inermis	C_3																																									BRIN2
	Aria caryophyllea																																										
AVBA	Avena barbata	C_3																																									AVBA
CYDA	Cynodon dactylon	C_4																																									CYDA
STPU2	Stipa pulchra	C_3+																																									STPU2
BRCA5	Bromus carinatus	C_3+																																									BRCA5
ELGL	Elymus glaucus	C_3																																									ELGL
FEID	Festuca idahoensis	C_3																																									FEID
CAREX	Carex sp.	C_3+																																									CAREX
AGROP2	Agropyron inermis	C_3																																									AGROP2
CAEL2	Carex eleocharis	C_3																																									CAEL2
	Unidentified grasses																																										

Appendix Table IV.3 (Continued)

SCS PLANT CODE	Ref. 61 EA & FA	Summer Good	Summer Poor	Ref. 62 EA	Winter	Ref. 63 FA	Winter Light Stocking	I	II	III	IV	Winter Heavy Stocking	I	II	III	IV	Ref. 64 RA	Summer 1964	Summer 1965	Ref. 72 EA & RA	Summer	Ref. 77 RA & EA	June-August RA	June-August EA	Ref. 80 EA	Summer	Ref. 82 EA	Summer Sage-brush	Summer Aspen	Ref. 84 CP	Winter 1946-47	Winter 1947-48	Summer	Ref. 86 RA	Summer	Ref. 94 OE	Ewes	Lambs	Ref. 97 FA	Summer	Ref. 98 FA	Grass Range	Saltbush Range	Sage brush Range	Ref. 105 RA	Yearly	Ref. 127 OE	Summer	Ref. 134 EA	Summer	SCS PLANT CODE
		28	25																				95	82				51	43		17	33	42		12		19	10		42								29		16	
CAEL3																																																			CAEL3
FEOV																																																			FEOV
FERU2																																																			FERU2
KOCR																							7	9																											KOCR
BOGR2																							5									8														23					BOGR2
ARIST																																																			ARIST
AGROP2																																																			AGROP2
STIPA																																																			STIPA
ORHY					27			55		19			23					7	27												10	6											20	12							ORHY
HIJA													25			48																5											7								HIJA
STCO4					16													49	37				14	15																			17	8							STCO4
SPCR																																																			SPCR
								34		78			32		95																	10											15								
AGSP																																																			AGSP
STLC4																																																			STLE4
AGCR																							18	14																											AGCR
POA++																																																			POA++
AGSM																		13	18				11	10																						8					AGSM
POSE																			9				6																												POSE
POFE																																																			POFE
BROMU																					34					65																									BROMU
GAVE3																																																			GAVE3
																					5					15																									
AGDA																																																			AGDA
																							15	10																											
BRIN2																							11	11																											BRIN2
																										5																									
AVBA																										11																									AVBA
CYDA																										30																									CYDA
STPU2																										23																									STPU2
BRCAS																																	19																		BRCAS
ELGL																																	20																		ELGL
FEID																																			6																FEID
CAREX																																					8											12			CAREX
AGROP2																																																			AGROP2
CAEL2																																														12					CAEL2
																										12																									

+ Provisional photosynthetic pathway assignment

Appendix Table IV.3. Sheep, diet components with composition proportion of 5 percent or greater compiled from the scientific literature.

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 7 EA	Summer July - August 1966-67	Early Summer	Mid Summer	Late Summer	Ref. 8 EA	Average 1966-67 Carter Mountain (Free grazing)	Average 1966-67 Meeteetse Creek (Herded)	Early July to Mid Sept.	Ref. 12 EA	Summer	Winter	Ref. 28 FA	Yearly	Ref. 40 FA	Winter Range	Ref. 41 BC	Heavy grazing	Moderate grazing	Light grazing	No other use	Ref. 46 FA & EA	Location 1 - Good	Location 1 - Poor	Location 2 - Good	Location 2 - Poor	Ref. 47 CP	1946-48	Ref. 49 EA	Winter	July	Ref. 57 OE	Summer Range	Spring Range	Ref. 58 RA	April - Sept.	Oct. - March	Year	Ref. 59 EA	Spring	SCS PLANT CODE
	TOTAL FORBS				71	78	80		52	65	58		56	68						8	15	13	42												22			11	9	10		70	
ASFO	Aster foliaceus			11	6	8	19																																				ASFO
POMO3	Polygonum montanum			9	7	9	13																																				POMO3
	Rumex paucifolius	C_3*		6	5	8																																					
POGR9	Potentilla gracilis	C_4*		20	24	13	25																																				POGR9
AGGL	Agoseris glauca	C_3		6	6	7	6																																				AGGL
HAFL2	Hackelia floribunda					5																																					HAFL2
GEVI2	Geranium viscosissimum																																										GEVI2
OSOC	Osmorhiza occidentalis					5																																					OSOC
GERO2	Geum rossii	C_3*							10	10	10																																GERO2
POBI6	Polygonum bistortoides								8	14	11																																POBI6
TRDA2	Trifolium dasyphyllum	C_3*							14	14	14																																TRDA2
TRNA2	Trifolium nanum	C_3*							8	13	10																																TRNA2
ARCA14	Artemisia carruthii												23	22																													ARCA14
SPCO	Sphaeralcea coccinea	C_3											8	10																													SPCO
VERBE	Verbena	C_4											16	20																													VERBE
ASTRA	Astragulus sp.	C_3*											7	14																													ASTRA
ATRIP	Atriplex sp.															47																											ATRIP
ATCO	Atriplex confertifolia	C_4																											31														ATCO
	Mertensia leonardi																																		9								
TAOF	Taraxacum officinale	C_3																																	7								TAOF
TRIFO	Trifolium sp.	C_3*																																	6								TRIFO
ERODI	Erodium sp.																																						7				ERODI
BASA3	Balsamorhiza sagittata	C_3																																								66	BASA3
	Kochia vestita	C_4*																																									
ANAR	Anagallis arvenis																																										ANAR
CARDU	Carduus sp.																																										CARDU
CIRSI	Cirsium sp.																																										CIRSI
DAPU3	Daucus pusillus	C_3*																																									DAPU3
ERBO	Erodium botrys																																										ERBO
GAPAS	Galium parisiense	C_3*																																									GAPAS
HYGL2	Hypochaeris glabra																																										HYGL2
LICI	Linanthus ciliatus																																										LICI
MADIA	Madia sp.																																										MADIA
MEHI	Medicago hispida	C_3*																													2-10	11											MEHI
SICA	Silene gallica	C_3*																																									SICA
TONO	Torilis nodosa																																										TONO
LALE2	Lathyrus leucanthus																																										LALE2
SOLID	Solidago sp.	C_4*																																									SOLID
SECR	Senecio crassulus	C_4*																																									SECR
	Helianthus laetiflorus	C_4*																																									
TARAX	Taraxacum sp.	C_3*																																									TARAX
ASTER	Aster sp.																																										ASTER
CHVI6	Chrysopsis villosa																																										CHVI6
ATNU2	Atriplex nutallii	C_4																																									ATNU2
LUPIN	Lupinus sp.	C_3																																									LUPIN
HICY	Hieracium cynoglossoides	C_4*																																									HICY
	Unidentified forbs				12	10	5																																			5	

Appendix Table IV.3 (Continued)

SCS PLANT CODE	Ref. 61 EA & FA	Summer Good	Summer Poor	Ref. 62 EA	Winter	Ref. 63 FA	Winter Light Stocking	I	II	III	IV	Winter Heavy Stocking	I	II	III	IV	Ref. 64 RA	Summer 1964	Summer 1965	Ref. 72 EA & RA	Summer	Ref. 77 RA & EA	June-August RA	June-August EA	Ref. 80 EA	Summer	Ref. 82 EA	Summer Sagebrush	Summer Aspen	Ref. 84 CP	Winter 1946-47	Winter 1947-48	Summer	Ref. 86 RA	Summer	Ref. 94 OE	Ewes	Lambs	Ref. 97 FA	Summer	Ref. 98 FA	Grass Range	Saltbush Range	Sagebrush Range	Ref. 105 RA	Yearly	Ref. 127 OE	Summer	Ref. 134 EA	Summer	SCS PLANT CODE
		34	33																					14				26	49				30		80		58	40		37								70		84	
ASFO																																																		6	ASFO
POMO3																																																		5	POMO3
																																																		7	
POCR9																																																		32	POCR9
AGGL																																																14		6	AGGL
HAFL2																																																			HAFL2
GEVI2																																																			GEVI2
																																			12																
OSOC																																																			OSOC
GERO2																																																			GERO2
POBI6																																																			POBI6
TRDA2																																																			TRDA2
TRNA2																																																			TRNA2
ARCA14																																																			ARCA14
SPCO																																																			SPCO
																																														13					
VERBE																																																			VERBE
ASTRA																																																			ASTRA
ATRIP																																																			ATRIP
ATCO																																																			ATCO
					23																										13	48											25	5							
TAOF																																					11	5													TAOF
TRIFO																					6					17																									TRIFO
ERODI																																																			ERODI
BASA3																																																			BASA3
													20																																						
ANAR																										7																									ANAR
CARDU																										15																									CARDU
CIRS1																										6																									CIRS1
DAPU3																										6																									DAPU3
ERBO																										14																									ERBO
GAPAS																										13																									GAPAS
HYGL2																										5																									HYGL2
LICI																										6																									LICI
MADIA																										23																									MADIA
MEHI																										32																									MEHI
SIGA																										7																									SIGA
TONO																										8																									TONO
LALE2																																	44				9	10													LALE2
SOLID																																			17																SOLID
SECR																																																		5	SECR
																																			15																
TARAX																																			9																TARAX
ASTER																																			7																ASTER
CHVI6																																					10														CHVI6
ATHU2																																											10	7							ATHU2
LUPIN																																																7			LUPIN
HICY																																																5			HICY
																										29									20													8		16	

+ Provisional photosynthetic pathway assignment

Appendix Table IV.3. Sheep, diet components with composition proportion of 5 percent or greater compiled from the scientific literature.

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 7 EA	Summer July - August 1966-67	Early Summer	Mid Summer	Late Summer	Ref. 8 EA	Average 1966-67 Carter Mountain (Free grazing)	Average 1966-67 Meeteetse Creek (Herded)	Early July to Mid Sept.	Ref. 12 EA	Summer	Winter	Ref. 28 FA	Yearly	Ref. 40 FA	Winter Range	Ref. 41 BC	Heavy grazing	Moderate grazing	Light grazing	No other use	Ref. 46 FA & EA	Location 1 - Good	Location 1 - Poor	Location 2 - Good	Location 2 - Poor	Ref. 47 CP	1946-48	Ref. 49 EA	Winter	July	Ref. 57 OE	Summer Range	Spring Range	Ref. 58 RA	April - Sept.	Oct. - March	Year	Ref. 59 EA	Spring	SCS PLANT CODE
	TOTAL SHRUBS																	50		14	23	27	30		75	53	28	38		75					19	36		10		6			
SAVE4	Sarcobatus vermiculatus															5																											SAVE4
	Yellowbrush																									26	23	35															
CULAS	Eurotia lanata																								16	16	43	23		23													EULAS
ARTR2	Artemisia tridentata	C_3																								10		9															ARTR2
	Artemisia nova																													8													
CHVIS	Chrysothamnus stenophyllus	C_4*																												10													CHVIS
POTRS	Populus tremuloides																																		7								POTRS
PRVI	Prunus virginiana																																		5								PRVI
	Symphoricarpos neophilus																																		7								
CEMO2	Cercocarpus montanus																																			26							CEMO2
CHVIL	Chrysothamnus lanceolatus	C_4*																																		10							CHVIL
ADFA	Adenostoma fasciculatum																																					5					AOFA
ATCA2	Atriplex canescens	C_4																																									ATCA2
SIHY	Sitanion hystrix	C_3																																									SIHY
QUERC	Quercus sp.																																										QUERC
AMAL2	Amelanchier alnifolia	C_3*																																									AMAL2
	Prunus demissa																																										
PUTR2	Purshia tridentata																																										PUTR2
SYOR2	Symphoricarpos vaccinioides																																										SYOR2
	Symphoricarpos oreophilus																																										
ARFR4	Artemisia frigida	C_3																																									ARFR4
EREF	Eriogonum effusum	C_4*																																									EREF
SYMPH	Symphoricarpos sp.																																										SYMPH

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 7 EA	Summer July - August 1966-67	Early Summer	Mid Summer	Late Summer	Ref. 8 EA	Average 1966-67 Carter Mountain (Free grazing)	Average 1966-67 Meeteetse Creek (Herded)	Early July to Mid Sept.	Ref. 12 EA	Summer	Winter	Ref. 28 FA	Yearly	Ref. 40 FA	Winter Range	Ref. 41 BC	Heavy grazing	Moderate grazing	Light grazing	No other use	Ref. 46 FA & EA	Location 1 - Good	Location 1 - Poor	Location 2 - Good	Location 2 - Poor	Ref. 47 CP	1946-48	Ref. 49 EA	Winter	July	Ref. 57 OE	Summer Range	Spring Range	Ref. 58 RA	April - Sept.	Oct. - March	Year	Ref. 59 EA	Spring	SCS PLANT CODE
	OTHER																																										
	Unidentified plants																																										

Appendix Table IV.3 (Continued)

SCS PLANT CODE	Ref. 61 EA & FA	Summer Good	Summer Poor	Ref. 62 EA	Winter	Ref. 63 FA	Winter Light Stocking	I	II	III	IV	Winter Heavy Stocking	I	II	III	IV	Ref. 64 RA	Summer 1964	Summer 1965	Ref. 72 EA & RA	Summer	Ref. 77 RA & FA	June-August RA	June-August EA	Ref. 80 EA	Summer	Ref. 82 EA	Summer Sage-brush	Summer Aspen	Ref. 84 CP	Winter 1946-47	Winter 1947-48	Summer	Ref. 86 RA	Summer	Ref. 94 OE	Ewes	Lambs	Ref. 97 FA	Summer	Ref. 98 FA	Grass Range	Saltbush Range	Sage brush Range	Ref. 105 RA	Yearly	Ref. 127 OE	Summer	Ref. 134 EA	Summer	SCS PLANT CODE
		38	42																									23	8		83	67	28				23	50		21											
SAVE4																																																			SAVE4
EULAS					11			5	87		38		16	70	5	50															45											10	10								EULAS
AATR2					10													18																										35							AATR2
					14																										11	5												12							
CHVIS																																																			CHVIS
																															11	8											6	8							
POTRS																																						8													POTRS
PRV1																																																			PRV1
CEMO2																																																			CEMO2
CHVIL																																																			CHVIL
ADFA																																																			ADFA
ATCA2									12					7																																					ATCA2
SIHY																		10																								10									SIHY
QUERC																					7																														QUERC
AMAL2																																																			AMAL2
																																	7																		
																																	6																		
PUTR2																																	10																		PUTR2
SYOR2																																																			SYOR2
																																	5																		
																																					17	36													
ARFR4																																														18					ARFR4
EREF																																														10					EREF
SYMPH																																			7																SYMPH

SCS PLANT CODE	Ref. 61 EA & FA	Summer Good	Summer Poor	Ref. 62 EA	Winter	Ref. 63 FA	Winter Light Stocking	I	II	III	IV	Winter Heavy Stocking	I	II	III	IV	Ref. 64 RA	Summer 1964	Summer 1965	Ref. 72 EA & RA	Summer	Ref. 77 RA & FA	June-August RA	June-August EA	Ref. 80 EA	Summer	Ref. 82 EA	Summer Sage-brush	Summer Aspen	Ref. 84 CP	Winter 1946-47	Winter 1947-48	Summer	Ref. 86 RA	Summer	Ref. 94 OE	Ewes	Lambs	Ref. 97 FA	Summer	Ref. 98 FA	Grass Range	Saltbush Range	Sage brush Range	Ref. 105 RA	Yearly	Ref. 127 OE	Summer	Ref. 134 EA	Summer	SCS PLANT CODE
																										24																6	11	9							

+ Provisional photosynthetic pathway assignment

Appendix Table IV.4. Sheep, additional diet components with composition proportion of less than 5 percent compiled from the scientific literature.

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
S- 7		ASIN3	Aster integrifolius
		LIFI	Ligusticum filicinum
		HAFL2	Hackelia floribunda
		GEVI2	Geranium viscossissimum
		OSOC	Osmorhiza occidentalis
		DEOC	Delphinium occidentale
		SECR	Senecio crassulus
		ACMI2	Achillea millefolium
			Unidentified forbs
S- 8		POAL2	Poa alpina
		CAAL6	Carex albo-nigra
		CABI5	Carex bigelowii
		CAEB	Carex ebenea
		CAEL3	Carex elynoides
		CAOB4	Carex obtusata
		DECA5	Deschampsia caespitosa
		KOCR	Koeleria cristata
		BEAL	Besseya alpina
		SEST2	Sedum stenopetalum
		POFE	Poa fendleriana
S- 12	Spring/Summer	BOCU	Bouteloua curtipendula
		PAHA	Panicum hallii
		GUSA2	Gutierrezia sarothrae
			Lemonweed
		BEHA	Berberis haematocarpia
		SIHY	Sitanion hystrix
		LEGO	Lesquerella gordonii
	Fall/Winter	ARIST	Aristida sp.
		BOCU	Bouteloua curtipendula
		QUUN	Quercus undulata
		LYPH	Lycurus phleoides
		PAHA	Panicum hallii
		GUSA2	Gutierrezia sarothrae
			Lemonweed
		ASTRA	Astragalus sp.
		SIHY	Sitanion hystrix
		BEHA	Berberis haematocarpa
		SPCR	Sporobolus cryptandrus
S- 28	Annual Average	ARTEM	Artemisia sp.
		EULA5	Eurotia lanata
		PUTR2	Purshia tridentata
		ORHY	Oryzopsis hymenoides
		CAREX	Carex sp.
		BROMU	Bromus sp.
		*FESTU	Vulpia sp.
		POA++	Poa sp.
		SAKA	Salsola kali
		SYMPH	Symphoricarpos sp.
		SPORO	Sporobolus sp.
		CHNA2	Chrysothamnus nauseosus
		SPHAE	Sphaeralcea sp.
		DIST	Distichlis stricta
S- 46	Location 1 Good	CHVIS	Chrysothamnus stenophyllus
		ARTR2	Artemisia tridentata
		SPHAE	Sphaeralcea sp.
	Loaction 1 Poor	STCO4	Stipa comata
		SPHAE	Sphaeralcea sp.
		SAKA	Salsola kali
	Location 2 Good	SITAN	Sitanion sp.
		ARIST	Aristida sp.
		SPCR	Sporobolus cryptandrus
		ARTR2	Artemisia tridentata
		SPHAE	Sphaeralcea sp.
		SAKA	Salsola kali

Appendix Table IV.4. (Continued)

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
	Location 2 Poor	ARIST	Aristida sp.
		STCO4	Stipa comata
		SPCR	Sporobolus cryptandrus
		SPHAE	Sphaeralcea sp.
		SAKA	Salsola kali
S- 47		ARSP5	Artemisia spinescens
		EPNE	Ephedra nevadensis
		GRSP	Grayis spinosa
		GUSA2	Gutierrezia sarothrae
		AGSP	Agropyron spicatum
		ARLO3	Aristida longiseta
		BOGR2	Bouteloua gracilis
		BRTE	Bromus tectorum
		HIJA	Hilaria jamesii
		SIHY	Sitanion hystrix
		STCO4	Stipa comata
		TRPI2	Trioda pilosa
		SAKA	Salsola kali
S- 57	Spring	PRVI	Prunus virginiana
		CAREX	Carex sp.
			Festuca subra
	Summer	AGSP	Agropyron spicatum
		POPR	Poa pratensis
	Spring - Sage Oak Range	ARARN	Artemesia nova
		ARTR2	Artemesia tridentata
		PUTR2	Purshia tridentata
		QUGA	Quercus gambelii
		CALI4	Castilleja linariaefolia
		ERIGE2	Erigeron sp.
		SIHY	Sitanion hystrix
		STCO4	Stipa comata
		STLE4	Stipa lettermani
	Spring - Pinyon Juniper Range	CALI4	Castilleja linariaefolia
		ERIGE2	Erigerion sp.
		AGSP	Agropyron spicatum
		SIHY	Sitanion hystrix
		STCO4	Stipa comata
		STLE4	Stipa lettermani
S- 58		ERODI	Erodium sp.
		ADFA	Adenostoma fasciculatum
		TRAE	Triticum aestivum
		QUDU	Quercus dumosa
		TRIFO	Trifolium sp.
		BRODI	Brodiaea sp.
		QUERC	Quercus sp.
		EQUIS	Equisetum sp.
		RANUN	Ranunculus sp.
		QUDO	Quercus douglasii
		VICIA	Vicia sp.
		QUWIZ	Quercus wislizenii
		ARCTO3	Arctostaphylos sp.
		QULO	Quercus lobata
		RHDI	Rhus diversiloba
		SALIX	Salix sp.
		MEHI	Medicago hispida
		ARME	Arbutus mensiesii
		CECU	Ceanothus cuneatus
		CEIN3	Ceanothus integerrimus
		RHTR	Rhus trilobata
		MESA	Medicago sativa
			Usneaceae
		CEME2	Centaurea melitensis
			Compositae
		SIGA	Silene gallica
		CLARK	Clarkia sp.
			Polypodiaceae

Appendix Table IV.4. (Continued)

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
S- 59		ORHY ARTR4 ALLIU COUM SEIN2	Oryzopsis hymenoides Artemisia tripartita Allium sp. Comandra umbellata Senecio integerrimus
S- 63	Area I: Light Stocking	ATCO HIJA EPNE	Atriplex confertifolia Hilaria jamesii Ephedra nevadensis
	Area I: Heavy Stocking	ATCO EPNE	Atriplex confertifolia Ephedra nevadensis
	Area II: Light Stocking	ATCO ARARN	Atriplex confertifolia Artemisia nova
	Area II: Heavy Stocking	ATCO ARARN	Atriplex confertifolia Artemisia nova
	Area III: Light Stocking	ATCO EULA5	Atriplex confertifolia Eurotia lanata
	Area III: Heavy Stocking	ATCO	Atriplex confertifolia
	Area IV: Light & Heavy Stocking	ATCO	Atriplex confertifolia
S- 64	Summer 1964	CHVI8 POSE EUROT CAOB4	Chrysothamnus viscidiflorus Poa secunda Eurotia sp. Carex obtusata
	Summer 1965	CHVI8 EUROT SIHY	Chrysothamnus viscidiflorus Eurotia sp. Sitanion hystrix
S- 72	Summer	AVBA STPU2 CYDA AICA	Avena barbata Stipa pulchra Cynodon dactylon Aira carophyllea Gassium parisiense
S- 77	Rumen	AGSMM ORHY CAREX SPCO ARFR4	Agropyron smithii molle Oryzopsis hymenoides Carex sp. Sphaeralcea coccinea Missouri vetch Striated vetch Foothill bladderpod Artemisia frigida
	Esophageal	POSE AGSMM SPCO BOGR2 ORHY CAREX ARFR4 CHVI8 CHNA2 EULA5	Poa secunda Missouri vetch Foothill bladderpod Agropyron smithii molle Striated vetch Sphaeralcea coccinea Bouteloua gracillis Oryzopsis hymenoides Carex sp. Artemisia frigida Chrysothamnus viscidiflorus Chrysothamnus nauseosus Eurotia lanata Phlox bryoides Parsnelia mollinocula
S- 80	Summer	MICA GODET LUBI ORTHO LOMU PLAGI HORDE	Micropus californicus Godetra sp. Lupinus bicolor Orthocarpus sp. Lolium multiflorum Plagiobothrys sp. Hordeum sp.

Appendix Table IV.4. (Continued)

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
		ERSE3	Eremocarpus setigerus
		CERAS	Cerastium sp.
		CYEC	Cynosurus echinatus
		JUNCU	Juncus sp.
		VERAT	Veratrum sp.
		ACHYR	Achyrachaena mollis
		PHTU	Phalaris tuberosa
		POA++	Poa sp.
		GITR2	Gilia tricolor
		*TRIOD	Specularia sp.
		BRMI2	Briza minor
		FIGA	Filago gallica
		POLYP	Polypodium sp.
			Spanish moss
S- 84	Summer		Thalictrum cendleri
		AGSU	Agropyron subsecundum
		HEUN	Helianthella uniflora
		BASA3	Balsamorhiza sagittata
		LIRU4	Lithospermum ruderale
		SESE2	Senecio serra
		LUCA	Lupinus caudatus
		OSOC	Osmorhiza occidentalis
		*ACMIL	Achillea lanulosa
		ASEN2	Aster engelmannii
		VIAM	Vicia americana
		AGUR	Agastache urticifolia
		DECA6	Descurainia californica
		PHHE2	Phacelia heterophylla
			Polemoniun albiforum
			Aster fremontii
		ORLU2	Orthocarpos luteus
	Winter	BOGR2	Bouteloua gracilis
		HIJA	Hilaria jamesii
		AGSP	Agropyron spicatum
		GUSA2	Gutierrezia sarothrae
		ARLO3	Aristida longiseta
		STCO4	Stipa comata
		EPNE	Ephedra nevadensis
		ARSP5	Artemesia spinesuns
		GRSP	Grayia spinosa
		BRTE	Bromus tectorum
		*TRPI2	Triodia pilosus
		SAKAT	Salsola kali var. tenuifolia
		TESP2	Tetradymia spinosa
S- 94		*AGTR	Agropyron pauciflorum
			Agropyron subsecundum
		BRCI2	Bromus cilatus
		BRCA5	Bromus carinatus
		FETH	Festuca thurberi
		FEOV	Festuca ovina
		POPR	Poa pratensis
		POFE	Poa fendleriana
		POCO	Poa compressa
		STLE4	Stipa lettermani
		STCO3	Stipa columbiana
		AMAL2	Amelanchier alnifolia
			Prunus melanocarpa
		*VAMY2	Vaccinium oreophilum
		*ACMIL	Achillea lanulosa
		DEBA2	Delphinium barbeyi
		ERIGE2	Erigeron sp.
		FRSP	Frasera speciosa
		GABO2	Galium boreale
		GERI	Geranium richardsoni
		HEHO	Helenium hoopesi
		OSOB	Osmorhiza obtusa

Appendix Table IV.4. (Continued)

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
		PEDIC	Pedicularis sp.
		SENEC	Senecio sp.
		PSMO	Pseudocymopterus mantanus
		THFE	Thalictrum fendleri
		THMO3	Thermopsis montana
S- 98	Grass Range	ARARN	Artemisia nova
		ARSP5	Artemisia spinescens
		ATCO	Atriplex confertifolia
		CHVIS	Chrysothamnus stenophyllus
		KOAMV	Kochia vestita
		AGSM	Agropyron smithii
		AGIN	Agropyron inerme
	Saltbrush Range	ARARN	Artemisia nova
		ARSP5	Artemisia spinescens
		KOAMV	Kochia vestita
		HIJA	Hilaria jamesii
		SIHY	Sitanion hystrix
		SPAI	Sporobolus airoides
		SPCR	Sporobolus cryptandrus
	Sagebrush Range	ARSP5	Artemisia spinescens
		EULA5	Eurotia lanata
		AGSM	Agropyron smithii
		ELCI2	Elymus cinereus
		HIJA	Hilaria jamesii
		ORHY	Oryzopsis hymenoides
		SIHY	Sitanion hystrix
		SPCR	Sporobolus cryptandrus
		STCO4	Stipa comata
S-105		ARLO3	Aristida longiseta
		BUDA	Buchloe dactyloides
		SPCR	Sporobolus cryptandrus
		BRTE	Bromus tectorum
		FEOC2	Festuca octoflora
		ORHY	Oryzopsis hymenoides
		STCO4	Stipa comata
		CIUN	Cirsium undulatum
		ERIGE2	Erigeron sp.
		EVNU	Evolvulus nuttallianus
			Heterotheca villosa
		KOSC	Kochia scoparia
		LIPU	Liatris punctata
		OEAL	Oenothera albicaulis
		OECO2	Oenothera coronopifolia
		PSTE3	Psoralea tenuiflora
		SAKA	Salsola kali
		SOSE4	Sophora sericea
		THME	Thelesperma megapotanicum
		ALTE	Allium textile
		MATA3	Aster tanacetifolius
		ASTRA	Astragalus sp.
		BAOP	Bahia oppositifolia
		CRYPT	Cryptantha sp.
		CYMO	Cymoptermus montanus
		ERBE2	Erigeron bellidiastrum
		LARE	Lappula redowskii
		LEDE	Lepidium densiflorum
		PAPAG	Plantago purshii
		TROC	Tradescantia occidentalis
		ARFI2	Artemisia filifolia
		ATCA2	Atriplex canescens
		CHNA2	Chrysothamnus nauseosus
		GUSA2	Gutierrizia sarothrae
		YUGL	Yucca glauca
			Parmelia chlorochroa

Appendix Table IV.4. (Continued)

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
S-127		AGROP2	Agropyron sp.
		BROMU	Bromus sp.
		DANTH	Danthonia sp.
		FESC	Festuca scabrella
		KOCR	Koeleria cristata
		PHLEU	Phleum sp.
		POA++	Poa sp.
		STIPA	Stipa sp.
		ACMI2	Achillea millefolium
		ALLIU	Allium sp.
		ANPA4	Antennaria parviflora
		ARCA7	Arenaria capillaris
		ARNIC	Arnica sp.
		ASTRA	Astragalus sp.
		CEAR4	Cerastium arvense
		CIRSI	Cirsium sp.
		DOCO	Dodecatheon conjugens
		ERIGE2	Erigeron sp.
		ERIOG	Eriogonum sp.
		FRVI	Fragaria virginiana
		GATR2	Galium trifidum
		GECA	Gentiana calycosa
		GEVI2	Geranium viscossissimum
		GNAPH	Gnaphalium sp.
		MEAL7	Mertensia alpina
		MICRO6	Microseris sp.
		OSMOR	Osmorhiza sp.
		PEDIC	Pedicularis sp.
		PEPR2	Penstemon procerus
		POTEN	Potentilla sp.
		SENEC	Senecio sp.
		SIAC	Silene acaulis
		TARAX	Taraxacum sp.
		TRIFO	Trifolium sp.
		VACCI	Vaccinium sp.
S-134		ACMI2	Achillea millefolium
		ASIN3	Aster integrifolius
		GEVI2	Geranium viscossissimum
		HAFL2	Hackelia floribunda

*Nomenclature or authority change since time of publication

Appendix Table IV.5. Bison, diet components with composition proportion of 5 percent or greater compiled from the scientific literature.

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 38 FA & EA	Summer FA Light Grazing	Moderate Grazing	Heavy Grazing	Summer EA Light Grazing	Moderate Grazing	Heavy Grazing	Ref. 88 EA & RA	May, June, August Light Grazing	Heavy Grazing	October, December, March Light Grazing	Heavy Grazing	Ref. 89 FA	Spring/ Summer	Winter	Ref. 125 FA	Spring	Summer	Fall	Winter	SCS PLANT CODE
	TOTAL GRASSES																						
BOGR2	Bouteloua gracilis	C_4		68	76	85	57	70	81		65	58	74	67									BOGR2
AGSM	Agropyron smithii	C_3		10	5		16	7	8		9	13	12	9									AGSM
SPCR	Sporobolus cryptandrus	C_4		7	10	6		5				6											SPCR
BUOA	Buchloe dactyloides	C_4					5	7	5														BUOA
CAHE5	Carex heliophila	C_3+					5	6			6	8											CAHE5
CAREX	Carex sp.	C_3+														65	82						CAREX
CAAT2	Carex atherodes	C_3+																	77	48	59	41	CAAT2
CALAM	Calamagrostis sp.	C_3+																	15	23	19	33	CALAM
CARO6	Carex rostrata	C_3+																			6	17	CARO6
	Other grasses															29	17						

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 38 FA & EA	Summer FA Light Grazing	Moderate Grazing	Heavy Grazing	Summer EA Light Grazing	Moderate Grazing	Heavy Grazing	Ref. 88 EA & RA	May, June, August Light Grazing	Heavy Grazing	October, December, March Light Grazing	Heavy Grazing	Ref. 89 FA	Spring/ Summer	Winter	Ref. 125 FA	Spring	Summer	Fall	Winter	SCS PLANT CODE
	TOTAL FORBS																						
TRIFO	Trifolium sp.	C_3+														5							TRIFO

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 38 FA & EA	Summer FA Light Grazing	Moderate Grazing	Heavy Grazing	Summer EA Light Grazing	Moderate Grazing	Heavy Grazing	Ref. 88 EA & RA	May, June, August Light Grazing	Heavy Grazing	October, December, March Light Grazing	Heavy Grazing	Ref. 89 FA	Spring/ Summer	Winter	Ref. 125 FA	Spring	Summer	Fall	Winter	SCS PLANT CODE
	TOTAL SHRUBS																						
ARFR4	Artemesia frigida	C_3												13									ARFR4
SALIX	Salix sp.																			8			SALIX

+ Provisional photosynthetic pathway assignment

Appendix Table IV.6. Bison, additional diet components with composition proportion of less than 5 percent compiled from the scientific literature.

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
BN- 38		ARLO	Arenaria longipedunculata
		BUOA	Buchloe dactyloides
		CAHE5	Carex heliophila
		STCO	Stachys coccinea
		*FEOC2	Vulpia ocotoflora
		SAKA	Salsola kali
		SPCO	Sphaeralcea coccinea
BN- 88	Summer	SPCR	Sporobolis cryptandrus
		ARLO3	Aristida longesita
		SPCO	Sphaeralcea coccinea
		FEOC2	Festuca octoflora
		STCO4	Stipa comata
		OECO2	Oenothera coronopifolia
		CIUN	Cirsium undulatum
		KOSC	Kochia scoparia
		LIPU	Liatrus punctata
		SAKA	Salsola kali
			Plantago purdii
		ALTE	Allium textile
		IVAX	Iva axillaris
		ORHY	Oryzopsis hymenoides
		EVNU	Evolvulus nuttallianus
		PSTE3	Psoralea tenuiflora
		OPPO	Opuntia polyacantha
		ARFR4	Artemesia frigida
		*MACA2	Aster tunacetifolius
			Thelepeoma negapotacium
		MUTO2	Muhlenbergia torreyi
		BUOA	Buchloe dactyloides
			Guara coccinia
		BRTE	Bromus tectorum
		EREF	Erjogonum effusum
		TROC	Tradescantia occidentalis
		LIIN2	Lithospermum incisum
		MILI3	Mirabilis linearis
		GUSA2	Gutierrezia sarothrac
		ASTRA	Astragalus sp.
	Fall/Winter	ARLO3	Aristida longesita
		CAHE5	Carex heliophila
		SPCR	Sporobolus cryptandrus
		EREF	Eriogonum effusum
		STCO4	Stipa comata
		SPCO	Sphaeralcea coccinea
		BRTE	Bromus tectorum
		OPPO	Opuntia polyacantha
		CHNA2	Chrysothamnus nauseosus
		GUSA2	Gutierrezia sarothrae
		BUOA	Buchloe dactyloides
		FEOC2	Festuca octoflora
		BAOP	Bahia oppositifolia
		ASTRA	Astragalus sp.
		YUGL	Yucca glauca
BN- 89	Spring/Summer	EQUIS	Equisetum sp.
	Winter	AGROP2	Agropyron
		SALIX	Salix sp.
BN-105		ARLO3	Aristida longiseta
		BUOA	Buchloe dactyloides
		MUTO2	Muhlenbergia torreyi
		SPCR	Sporobolus cryptandrus
		AGCR	Agropyron cristatum
		BRTE	Bromus tectorum
		FEOC2	Festuca octoflora
		ORHY	Oryzopsis hymenoides
		STCO4	Stipa comata
		CIUN	Crisium undulatum

Appendix Table IV.6. (Continued)

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
		ERIGE2	Erigeron sp.
		EVNU	Evolvulus nuttallianus
		GACO5	Gaura coccinea
			Heterotheca villosa
		KOSC	Kochia scoparia
		LIPU	Liatris punctata
		MILI3	Mirabilis linearis
		OEAL	Oenothera albicaulis
		OECO2	Oenothera coronopifolia
		PSTE3	Psoralea tenuiflora
		SAKA	Salsola kali
		THME	Thelesperma megapotamicum
		ALTE	Allium textile
		*MATA2	Aster Tancetifolius
		ASTRA	Astragalus sp.
		CRYPT	Cryptantha sp.
		LEDE	Lepidium densiflorum
		LIIN2	Lithospermum incisum
		*PLPAG	Plantago purshii
		SPCO	Sphaeralcea coccinea
		TROC	Tradescantia occidentalis
		ARFR4	Artemisia frigida
		ATCA2	Atriplex canescens
		CHNA2	Chrysothamnus nauseosus
		EREF	Erigonum effusum
		GUSA2	Gutierrizia sarothrae
		YUGL	Yucca glauca
		OPPO	Opuntia polyacantha
			Parmelia chlorochroa
BN-125	Spring	SALIX	Salix sp.
		CAAQ	Carex aquatilis
		CARO6	Carex rostrata
	Summer	CAAQ	Carex aquatilis
		CARO6	Carex rostrata
		GEAL3	Geum aleppicum
		AGTR	Agropyron trachycaulum
		JUBA	Juncus balticus
		CASI	Carex foenea
		CAAE	Carex aenea
		POTEN	Potentilla sp.
	Fall	SALIX	Salix sp.
		CAAQ	Carex aquatilis
		GEAL3	Geum aleppicum
		JUBA	Juncus balticus
		EQUIS	Equisetum sp.
	Winter	SALIX	Salix sp.
		CAAQ	Carex aquatilis
		JUBA	Juncus balticus

*Nomenclature or authority change since time of publication

Appendix Table IV.7. Bighorn Sheep, diet components with composition proportion of 5 percent or greater compiled from the scientific literature.

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 6 FA	Winter	Spring	Summer	Fall	Ref. 10 FA	Annual Diet	Ref. 14 BC & FA	BC Yearlong	FA Spring	FA Summer	Ref. 42 FA	Summer	Ref. 124 OE & RA	Yearlong	Ref. 130 FA	Winter 1978	Spring 1978	Summer 1978	Fall 1978	Winter 1979	Spring 1979	Ref. 133 OE & CP	Winter	SCS PLANT CODE
	TOTAL GRASSES			23	57	65	54								56				22	52	39	36	52	53		72	
TRIDE	Tridens sp.	C_4+							11																		TRIDE
EPNE	Ephedra nevadensis								9																		EPNE
MUPO2	Muhlenbergia porteri	C_4							12																		MUPO2
SPHAE	Sphaeralcea sp.								52																		SPHAE
ARWR	Aristida wrightii	C_4+							7																		ARWR
AGSP	Agropyron spicatum	C_3													15		30									37	AGSP
STCO4	Stipa comata	C_3													8												STCO4
KOCR	Koeleria cristata	C_3													9		7										KOCR
FESC	Festuca scabrella	C_3													13												FESC
FESTU	Festuca sp.	C_3+		7	8	11	11												5	11		6		5			FESTU
MUHLE	Muhlenbergia sp.	C_4+			18	7													7	16	10	9	14	8			MUHLE
BOGR2	Bouteloua gracilis	C_4			5	23	9																				BOGR2
POA++	Poa sp.	C_3		6	7	6	8										8										POA++
CAREX	Carex sp.	C_3+			12	15	14													8	10			17			CAREX
STIPA	Stipa sp.	C_3+					10																				STIPA
ARIST	Aristida sp.	C_4+											6														ARIST
BOUTE	Bouteloua sp.	C_4+										5	26										18	7			BOUTE
FEID	Festuca idahoensis	C_3																								23	FEID
	Unidentified grasses														13				8	17	15	18	16	16			

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 6 FA	Winter	Spring	Summer	Fall	Ref. 10 FA	Annual Diet	Ref. 14 BC & FA	BC Yearlong	FA Spring	FA Summer	Ref. 42 FA	Summer	Ref. 124 OE & RA	Yearlong	Ref. 130 FA	Winter 1978	Spring 1978	Summer 1978	Fall 1978	Winter 1979	Spring 1979	Ref. 133 OE & CP	Winter	SCS PLANT CODE
	TOTAL FORBS			11	10	6									32					7	13			15		17	
BASA	Balsamorhiza sagitta	C_3																									BASA
ACMI2	Achillea millefolium	C_3																									ACMI2
LUSE4	Lupinus sericeus	C_3																									LUSE4
YUGL	Yucca glauca	C_3		8	6																						YUGL
ERAB2	Erigonum abertianum	C_4+									15																ERAB2
EVAR	Evolvulus arizonicus	C_4+									7																EVAR
SIFI2	Sida filicaulis	C_3+									5																SIFI2
ERIOG	Erigonum sp.	C_4+										18															ERIOG
	Janusia sp.										15	46															
ARFR4	Artemisia frigida	C_3																								9	ARFR4
	Unidentified forbs			6											21					7	13						

Appendix Table IV.7. (Continued)

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 6 FA	Winter	Spring	Summer	Fall	Ref. 10 FA	Annual Diet	Ref. 14 BC & FA	BC Yearlong	FA Spring	FA Summer	Ref. 42 FA	Summer	Ref. 124 OE & RA	Yearlong	Ref. 130 FA	Winter 1978	Spring 1978	Summer 1978	Fall 1978	Winter 1979	Spring 1979	Ref. 133 OE & CP	Winter	SCS PLANT CODE
	TOTAL SHRUBS			67	33	29	44								13				76	41	48	61	45	32		8	
ARTEM	Artemisia sp.			60	23		27												55	22		20	14	7			ARTEM
CEMO2	Cercocarpus montanus					12															19						CEMO2
HODU	Holodiscus dumosus					10																					HODU
ACCO2	Acacia constricta										17																ACCO2
ACGR	Acacia greggii										11																ACGR
CAER	Calliandra eriophylla										6																CAER
CHILO	Chilopsis sp.	C_4										49	23														CHILO
ARFR4	Artemisia frigida	C_3															20										ARFR4
ATCA2	Atriplex canescens	C_4+																	8		7	28	9				ATCA2
YUGL	Yucca glauca	C_3																					8				YUGL
	Ceratoides lanata																						9	8			
	Unidentified shrubs				6		14								6				13	14	18	11	5	12			

+ Provisional photosynthetic pathway assignment

Appendix Table IV.8. Bighorn Sheep, additional diet components with composition proportion of less than 5 percent compiled from the scientific literature.

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
BHS- 6	Winter	MUHLE	Muhlenbergia sp.
		CAREX	Carex sp.
		BOGR2	Bouteloua gracillis
		STIPA	Stipa sp.
	Spring	CEMO2	Cercocarpus montanus
		HODU	Holodiscus dumosus
		STIPA	Stipa sp.
	Summer	ARTEM	Artemisia sp.
		STIPA	Stipa sp.
	Fall	MUHLE	Muhlenbergia sp.
		YUGL	Yucca glauca
BHS- 10		ACCO2	Acacia constricta
		TIOB	Tidestromia oblongifolia
		ERIOG	Eriogonum sp.
		BRRU2	Bromus rubens
		FRAN2	Fraxinus anomala
		OPUNT	Opuntia sp.
		PRJU	Prosopis juliflora
			Seed
		PHCA8	Phoradendron californicum
		*MABI	Aster biglovii
BHS- 14	Bite Count	DAWH2	Oasylirion wheeleri
		BOCU	Bouteloua curtipendula
		TRCA2	Trichachne californica
		MATA2	Machaeranthera tanacetifolia
			Janusia gracilis
		CHCO	Chamaesaracha coinoides
		ERWR	Eriogonum wrightii
		LOHU2	Lotus humistratus
		*ARLU	Artemisia gnaphalodes
		ORLU	Orobanche ludoviciana
		STEX	Stephanomeria exigua
		SPCO	Sphaeralcea coccinea
	Fecal Analysis/ Spring	JUNIP	Juniperus sp.
		ACACI	Acacia sp.
		QUERC	Quercus sp.
		OPUNT	Opuntia sp.
		YUCCA	Yucca sp.
		ARIST	Aristida sp.
		FESTU	Festuca sp.
		HILAR	Hilaria sp.
		ARTEM	Artemisia sp.
		CRYPT	Cryptantha sp.
		DESCU	Descurainia sp.
		ERIGE2	Erigeron sp.
		EVOLV	Evolvulus sp.
		LESQU	Lesquerella sp.
		LUPIN	Lupinus sp.
		MENTZ	Mentzelia sp.
		PLANT	Plantago sp.
	Fecal Analysis/ Summer	ACACI	Acacia sp.
		OPUNT	Opuntia sp.
		YUCCA	Yucca sp.
		FESTU	Festuca sp.
		HILAR	Hilaria sp.
		ARTEM	Artemisia sp.
		ERIGE2	Erigeron sp.
		ERIOG	Erigonum sp.
		EVOLV	Evolvulus sp.
		LUPIN	Lupinus sp.
		MENTZ	Mentzelia sp.

Appendix Table IV.8. (Continued)

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
BHS- 42	Summer	AMAL2	Amelanchier alnifolia
		LUSE4	Lupinus sericeus
		PRVI	Prunus virginiana
		ERHE2	Eriogonum heracleoides
		ERNI2	Eriogonum niveum
		ACMI2	Achillea millefolium
		BRTE	Bromus tectorum
		ARTR2	Artemisia tridentata
BHS-124		KOCR	Koeleria cristata
		BRTE	Bromus tectorum
		FEID	Festuca idahoensis
		AGROS2	Agrostis sp.
		STCO3	Stipa columbiana
		STRI2	Stipa richardsoni
		LUSE4	Lupinus sericeus
		ACMI2	Achillea millefolium
		ERIGE2	Erigeron sp.
		PHACE	Phacelia sp.
		ALCE2	Allium cernuum
		ERHE2	Eriogonum heracleoides
		RICE	Ribes cereum
		ARDR4	Artemisia dracunculoides
		ROSA+	Rosa sp.
		SALIX	Salix sp.
		PICO	Pinus conforta
		ARUV	Arctostaphylos uva-ursi
		VASC	Vaccinium scoparium
		PSMEG	Pseudotsuga menziesii var. glauca
		PIEN	Picea engelmannii
		SHCA	Shepherdia canadensis
			Ribes budsonianum
		RUID	Rubus idaeus
		ZYVE	Zygadenus venenosus
BHS-130	Winter 1978	CAREX	Carex sp.
		CEMO2	Cercocarpus montanus
	Spring 1978	ATCA2	Atriplex canescens
		CEMO2	Cercocarpus montanus
	Summer 1978	FESTU	Festuca sp.
		ARTEM	Artemisia sp.
	Fall 1978	CAREX	Carex sp.
		CEMO2	Cercocarpus montanus
	Winter 1979	FESTU	Festuca sp.
		CAREX	Carex sp.
	Spring 1979	YUGL	Yucca glauca
		ATCA2	Atriplex canescens
BHS-133		AGSU	Agropyron subsecundum
		AGTR	Agropyron trachycaulum
		BRJA	Bromus japonicus
		CARU	Calamagrostis rubescens
		CAREX	Carex sp.
		POA++	Poa sp.
		STVI4	Stipa viridula
		ACMI2	Achillea millefolium
		ARMI4	Artemisia michauxiana
		BASA3	Balsamorrhiza sagittata
		ERIGE2	Erigeron sp.
		LUPIN	Lupinus sp.
		PHHO	Phlox hoodii
		SOMI2	Solidgo missouriensis
		TRDU	Tragopogon dubius
		ARTR2	Artemisia tridentata
		CHVI8	Chrysothamnus viscidiflorus
		COST4	Cornus stolonifera
		JUCO6	Juniperus communis
		PRVI	Prunus virginiana
		RIBES	Ribes sp.
		ROAC	Rosa acicularis
		SALIX	Salix sp.

*Nomenclature or authority change since time of publication

Appendix Table IV.9. Pronghorn Antelope, diet components with composition proportion of 5 percent or greater compiled from the scientific literature.

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 3 OF	Spring-Summer	Ref. 9 FA	Spring	Summer	Fall	Winter	Ref. 22	Winter Wheatgrass, Needlegrass	Ref. 28 FA	Yearly	Ref. 34 FA	Light Grazing	Heavy Grazing	Ref. 35 RA	1950-51	Ref. 36 RA	Spring-Summer	Fall-Winter	Ref. 37 RO & BC	Yearly	Ref. 39 RA	Annual	Ref. 45 RA	Year Long	Fall-Winter	Ref. 48 RO,OE,RA	Nov.-March	June-July Wet Year	Ref. 50 RA	Year Long Average	Ref. 51 OE & RA	Spring-Summer	Fall-Winter	Ref. 52 RA	Oct.-Nov.	Ref. 53	Year Long Wheatgrass, Needlegrass	Ref. 54	Fall Grama-buffalograss	Ref. 64 RA	Summer 1964	Summer 1965	Fall & Winter 1964	Year Long Summary	Ref. 79	Shrub Savanna Year Long	Ref. 95 BC	April-August 1964	SCS PLANT CODE
	TOTAL GRASSES														44	52				5	9		25		13		6								6					11									7		22	
BOCU	Bouteloua curtipendula	C_4																																																	9	BOCU
BOGR2	Bouteloua gracilis	C_4													13	21																																			5	BOGR2
SPCR	Sporobolus cryptandrus	C_4																																																	6	SPCR
AGSM	Agropyron smithii	C_3														12																																				AGSM
BRTE	Bromus tectorum	C_3													24																																					BRTE
CAREX	Carex sp.	C_3*														18																																				CAREX

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 3 OF	Spring-Summer	Ref. 9 FA	Spring	Summer	Fall	Winter	Ref. 22	Winter Wheatgrass, Needlegrass	Ref. 28 FA	Yearly	Ref. 34 FA	Light Grazing	Heavy Grazing	Ref. 35 RA	1950-51	Ref. 36 RA	Spring-Summer	Fall-Winter	Ref. 37 RO & BC	Yearly	Ref. 39 RA	Annual	Ref. 45 RA	Year Long	Fall-Winter	Ref. 48 RO,OE,RA	Nov.-March	June-July Wet Year	Ref. 50 RA	Year Long Average	Ref. 51 OE & RA	Spring-Summer	Fall-Winter	Ref. 52 RA	Oct.-Nov.	Ref. 53	Year Long Wheatgrass, Needlegrass	Ref. 54	Fall Grama-buffalograss	Ref. 64 RA	Summer 1964	Summer 1965	Fall & Winter 1964	Year Long Summary	Ref. 79	Shrub Savanna Year Long	Ref. 95 BC	April-August 1964	SCS PLANT CODE
	TOTAL FORBS														54	43				28	14		61		51		43	13			95		16		39	23				23		82							58		20	
CHAEN	Chaenactis sp.			27																											30																					CHAEN
SPHAE	Sphaeralcea sp.	C_3*		44																											34																					SPHAE
ERIOG	Eriogonum sp.	C_4*		8																											12																					ERIOG
GILIA	Gilia sp.	C_4*		8																											10																					GILIA
	Aster multiflorus																																																		9	
PHLOX	Phlox	C_3*																14															14																			PHLOX
EUMAB	Euphorbia marginata	C_4*																																																	6	EUMAB
EREF	Eriogonum effusum	C_4*														7																																				EREF
STCO6	Streptanthus cordatus					5	29	7																																												STCO6
SAKA	Salsola kali	C_4											5																																							SAKA
SPCO	Sphaeralcea coccinea	C_3													25	16																																				SPCO
THELC	Thelesperma filifolium	C_4*													7																																					THELE
POTEN	Potentilla sp.																																																			POTEN

Appendix Table IV.9 (Continued)

SCS PLANT CODE	Ref. 96 RA	Yellowstone Winter	Spring	Summer	Fall	Bison Range Winter	Spring	Summer	Fall	Ref. 105 RA	Yearly	Ref. 106	Summer & Winter Sage brush Steppe	Ref. 107 OE	Grama-needle grass wheat-grass Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Sage-brush Steppe Spring	Summer	Fall	Winter	Ref. 108	Fall Grama-needle-grass Wheat-grass	Ref. 109	Fall Grama-needle-grass Wheat-grass	Ref. 110 RA	Sage-brush Steppe Average	Ref. 111	Sage-brush Steppe Spring	Grama-needle-grass Summer	Wheat-grass & Wheat-grass-needle grass Fall	Wheat-grass & Wheat-grass-needle-grass Winter	Ref. 112	Sage-brush Steppe Summer 1964	Fall 1964	Winter 1964	Fall 1965	Winter 1965	Ref. 113	Summer & Fall	Ref. 114	Grama-buffalo-grass & Sausage-blue-stem Prairie Year Long Averages	Ref. 115	Grama buffalo grass	SCS PLANT CODE
BOCU			18		5		32	15	8						13		6		6									7		7		20		8					7			10								BOCU
BOCR2											12																																							BOCR2
SPCR																																																			SPCR
AGSM																																																			AGSM
BRTE											5																																							BRTE
CAREX																																																			CAREX

SCS PLANT CODE	Ref. 96 RA	Yellowstone Winter	Spring	Summer	Fall	Bison Range Winter	Spring	Summer	Fall	Ref. 105 RA	Yearly	Ref. 106	Summer & Winter Sage brush Steppe	Ref. 107 OE	Grama-needle grass wheat-grass Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Sage-brush Steppe Spring	Summer	Fall	Winter	Ref. 108	Fall Grama-needle-grass Wheat-grass	Ref. 109	Fall Grama-needle-grass Wheat-grass	Ref. 110 RA	Sage-brush Steppe Average	Ref. 111	Sage-brush Steppe Spring	Grama-needle-grass Summer	Wheat-grass & Wheat-grass-needle grass Fall	Wheat-grass & Wheat-grass-needle-grass Winter	Ref. 112	Sage-brush Steppe Summer 1964	Fall 1964	Winter 1964	Fall 1965	Winter 1965	Ref. 113	Summer & Fall	Ref. 114	Grama-buffalo-grass & Sausage-blue-stem Prairie Year Long Averages	Ref. 115	Grama buffalo grass	SCS PLANT CODE
CHAEN		17	34	80	49	62	61	72	76				19		56	85	66		14	43	7		9	73				7		6		10		15	33	11			5	17			5		10		42		24	CHAEN
SPHAE																																																		SPHAE
ERIOG																																																			ERIOG
GILIA																																																			GILIA
PHLOX																																																			PHLOX
EUMA8																																																			EUMA8
EREF											5																																							EREF
STCO6											23																																							STCO6
SAKA											5																																							SAKA
SPCO																																																			SPCO
THELE																																																			THELE
POTEN																																																			POTEN

Appendix Table IV.9 (Continued)

SCS PLANT CODE	Ref. 116	Grama-buffalo-grass Sandsage blue-stem Prairie Year Long	Ref. 117	Year Long	Ref. 118	Sage brush Steppe Winter	Ref. 119	Sage-brush Steppe Sept.	Ref. 120	N. West Nevada Sage-brush August & Sept.	N. East Nevada Sage-brush August & Sept.	Ref. 121	Sage-brush Steppe Juniper Steppe Woodland Spring	Fall	Winter	Ref. 122 OE	Year Long	Ref. 123 FA	Winter	Spring	Summer	Fall	Ref. 132 FA	Winter	Spring	Summer	Fall	SCS PLANT CODE
		7		7		5		15											12	36	7	30			6			
BOCU																												BOCU
BOGR2																												BOGR2
SPCR																												SPCR
AGSM																												AGSM
BRTE																												BRTE
CAREX																												CAREX

SCS PLANT CODE	Ref. 116	Grama-buffalo-grass Sandsage blue-stem Prairie Year Long	Ref. 117	Year Long	Ref. 118	Sage brush Steppe Winter	Ref. 119	Sage-brush Steppe Sept.	Ref. 120	N. West Nevada Sage-brush August & Sept.	N. East Nevada Sage-brush August & Sept.	Ref. 121	Sage-brush Steppe Juniper Steppe Woodland Spring	Fall	Winter	Ref. 122 OE	Year Long	Ref. 123 FA	Winter	Spring	Summer	Fall	Ref. 132 FA	Winter	Spring	Summer	Fall	SCS PLANT CODE
		28		20		10		27		33	49		35	52			45		7	21	22	8			19	34	12	
CHAEN																												CHAEN
SPHAE																												SPHAE
ERIOG																										9		ERIOG
GILIA																												GILIA
PHLOX																												PHLOX
EUMAB																												EUMAB
EREF																												EREF
STCO6																												STCO6
SAKA																												SAKA
SPCO																												SPCO
THELE																												THELE
POTEN																									5	10		POTEN

+ Provisional photosynthetic pathway

Appendix Table IV.9. Pronghorn Antelope, diet components with composition proportion of 5 percent or greater compiled from the scientific literature.

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 3 OE	Spring-Summer	Ref. 9 FA	Spring	Summer	Fall	Winter	Ref. 22	Winter Wheatgrass, Needlegrass	Ref. 28 FA	Yearly	Ref. 34 FA	Light Grazing	Heavy Grazing	Ref. 35 RA	1950-51	Ref. 36 RA	Spring-Summer	Fall-Winter	Ref. 37 RO & BC	Yearly	Ref. 39 RA	Annual	Ref. 45 RA	Year Long	Fall-Winter	Ref. 48 RO,OE,RA	Nov.-March	June-July Wet Year	Ref. 50 RA	Year Long Average	Ref. 51 OE & RA	Spring-Summer	Fall-Winter	Ref. 52 RA	Oct.-Nov.	Ref. 53	Year Long Wheatgrass, Needlegrass	Ref. 54	Fall Grama-buffalograss	Ref. 64 RA	Summer 1964	Summer 1965	Fall & Winter 1964	Year Long Summary	Ref. 79	Shrub Savanne Year Long	Ref. 95 BC	April-August 1964	SCS PLANT CODE
	TOTAL SHRUBS															5				65	72		14		35		40	14		90					50	68				66									35		18	
PURSH	Purshia sp.					28	34																																													PURSH
ARTEM	Artemisia sp.					34	10	34	53		83		78					61															61																		18	ARTEM
JUNIP	Juniperus sp.	C_3*				9		12	29																																											JUNIP
ATRIP	Atriplex sp.												6																																							ATRIP
ARCA13	Artemisia cana																																					48														ARCA13
JUHO2	Juniperus horizontalis	C_3*																																				11														JUHO2
SYOC	Symphoricarpos occidentalis																																					17														SYOC
	Chrysothamnus nauseosus	C_4*																																				9														
CHVI8	Chrysothamnus viscidiflorus	C_4																																										86	86	46	58					CHVI8
ARTR2	Artemisia tridentata	C_3																																										11	13	51	38					ARTR2
ARFR4	Artemisia frigida	C_3																																																		ARFR4
CHRYS9	Chrysothamnus sp.	C_4*																																																		CHRYS9
RIBES	Ribes sp.																																																			RIBES
CERCO	Cercocarpus sp.																																																			CERCO
	OTHER																																																			
	Weeds																	6																																		
	Cacti																										11																									
	Wheat (heads)	C_3																																				8														
	Winter wheat	C_3																																																		
OPMA2	Opuntia macrorhiza																																																		40	OPMA2
	Cultivated crops																																					10														
	Unidentified other										17																															10										

Appendix Table IV.9 (Continued)

SCS PLANT CODE	Ref. 96 RA	Yellowstone Winter	Spring	Summer	Fall	Bison Range Winter	Spring	Summer	Fall	Ref. 105 RA	Yearly	Ref. 106	Summer & Winter Sagebrush Steppe	Ref. 107 OE	Grama-needlegrass-wheatgrass Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Sagebrush Steppe Spring	Summer	Fall	Winter	Ref. 108	Fall Grama-needlegrass-wheatgrass	Ref. 109	Fall Grama-needlegrass Wheatgrass	Ref. 110 RA	Sagebrush Steppe Average	Ref. 111	Sagebrush Steppe Spring	Grama-needlegrass Summer	Wheatgrass & Wheatgrass-needlegrass Fall	Wheatgrass & Wheatgrass-needlegrass Winter	Ref. 112	Sagebrush Steppe Summer 1964	Fall 1964	Winter 1964	Fall 1965	Winter 1965	Ref. 113	Summer & Fall	Ref. 114	Grama-buffalograss & Sausage-bluestem Prairie Year Long Averages	Ref. 115	Grama buffalograss	SCS PLANT CODE
PURSH		81	48	16	47	34	7	12	16						31	15	28	97	80	57	93	99	90	27	97	100		86		88		72		77	66	88	92		88	83	98	74	92		86		43		73	PURSH
ARTEM													81																																					ARTEM
JUNIP																																																		JUNIP
ATRIP																																																		ATRIP
ARCA13																																																		ARCA13
JUMO2																																																		JUMO2
SYOC																																																		SYOC
CHVI8																																																		CHVI8
AATR2																																																		AATR2
ARFR4											10																																							ARFR4
CHRYS9																																																		CHRYS9
RIBES																																																		RIBES
CERCO																																																		CERCO
OPMA2																																										14								OPMA2

Appendix Table IV.9 (Continued)

SCS PLANT CODE	Ref. 116	Grama-buffalo-grass Sandsage blue-stem Prairie Year Long	Ref. 117	Year Long	Ref. 118	Sage brush Steppe Winter	Ref. 119	Sage-brush Steppe Sept.	Ref. 120	N. West Nevada Sage-brush August & Sept.	N. East Nevada Sage-brush August & Sept.	Ref. 121	Sage-brush Steppe Juniper Steppe Woodland Spring	Fall	Winter	Ref. 122 OE	Year Long	Ref. 123 FA	Winter	Spring	Summer	Fall	Ref. 132 FA	Winter	Spring	Summer	Fall	SCS PLANT CODE
		65		47		85		58		64	43		64	47	96		52		84	37	68	60		95	76	63	86	
PURSH																												PURSH
ARTEM																								68	46	26	24	ARTEM
JUNIP																												JUNIP
ATRIP																								6			18	ATRIP
ARCA13																												ARCA13
JUMO2																												JUMO2
SYOC																												SYOC
CHVI8																												CHVI8
ARTR2																												ARTR2
ARFR4																												ARFR4
CHRYS9																								19	7	9	37	CHRYS9
RIBES																									7			RIBES
CERCO																										20		CERCO
				7																								
				19																								
OPMA2																												OPMA2

+ Provisional photosynthetic pathway assignment

Appendix Table IV.10. Pronghorn Antelope, additional diet components with composition proportion of less than 5 percent compiled from the scientific literature.

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
PA- 3		MACHA	Machaeranthera sp.
PA- 9	Winter	PURSH	Purshia sp.
		STCO6	Streptanthus cordatus
	Summer	JUNIP	Juniperous sp.
PA- 28	Annual Average	ASTRA	Astragalus
		OXYTR	Oxytropis
		ELCO	Elaeagnus commutata
		STIPA	Stipa sp.
		PUTR2	Purshia tridentata
		SAVE4	Sarcobatus vermiculatus
		CHNA2	Chrysothamnus nauseosus
		AGROP2	Agropyron sp.
		ORHY	Oryzopsis hymenoides
		CAREX	Carex sp.
		EULA5	Eurotia lanata
		BROMU	Bromus sp.
		CRYPT	Cryptantha sp.
		ROSA+	Rosa sp.
PA- 34	Light	AGSM	Agropyron smithii
		CAREX	Carex sp.
		*FEOC2	Vulpia octoflora
		ASPE5	Astragalus pectinatus
		BAOP	Bahia oppostifolia
		CHVI6	Chrysopsis villosa
		CYAC	Cymopterus acaulis
		DEPI	Descurainia pinnata
		EREF	Erigonum effusum
		IVAX	Iva axillaris
		LEDE	Lepidum densiflorum
		LEMO4	Leucocrinum montanum
		LOOR	Lomatium orientale
		OENOT	Oenothera sp.
		*PLPAG	Plantago purshii
		SAKA	Salsola kali
		SOSE4	Sophora sericea
		ARFR4	Artemisia frigida
		CHNA2	Chrysothamnus naseosus
		GUSA2	Gutierrezia sarothrae
	Heavy	BRTE	Bromus tectorum
		*FEOC2	Vulpia octoflora
		ASPE5	Astragalus pectiratus
		BAOP	Bahia oppostifolia
		CHVI6	Chrysopsis villosa
		CYAC	Cymopterus acaulis
		DEPI	Descurainia pinnata
		IVAX	Iva axillaris
		LEDE	Lepidum densiflorum
		LEMO4	Leucocrinum montanum
		LOOR	Lomatium orientale
		OENOT	Oenothera sp.
		*PLPAG	Plantago purshii
		SAKA	Salsola kali
		SOSE4	Sophora sericea
		THFI	Thelesperma filifolium
		ARFR4	Artemisia frigida
		CHNA2	Chrysothamnus naseosus
		GUSA2	Gutierrezia sarothrae
PA- 64	Summer 1964	AGSM	Agropyron smithii
		ORHY	Oryzopsis hymenoides
		STCO4	Stipa comata
		POSE	Poa secunda
		SIHY	Sitanon hystrix
	Summer 1965	AGSM	Agropyron smithii
		ORHY	Oryzopsis hymenoides
		POSE	Poa secunda
		CAOB4	Carex obtusata

Appendix Table IV.10. (Continued)

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
	Fall & Winter 1964	EUROT	Eurotia sp.
	Yearlong Summary	AGSM	Agropyron smithii
		ORHY	Oryzopsis hymenoides
		STCO4	Stipa comata
		POSE	Poa secunda
		EUROT	Eurotia sp.
		SIHY	Sitanon hystrix
		CAOB4	Carex obtusata
PA- 95		LYJU	Lygodesmia juncea
		PSTE3	Psoralea tenufolia
		PSAR2	Psoralea agrophylla
		SPCO	Sphaeralcea coccinea
		ARLO3	Aristida longiseta
PA-105		ARLO3	Aristida longiseta
		BOHI2	Bouteloua hirsuta
		BUDA	Buchloe dactyloides
		MUFI	Muhlenbergia filiculmis
		SCPA	Schedonnardus paniculatus
		SPAI	Sporobolus airoides
		SPCR	Sporobolus cryptandrus
		AGDE2	Agropyron desertorum
		AGSM	Agropyron smithii
		CAEL2	Carex eleocharis
		CAFI	Carex filifolià
		FEOC2	Festuca octoflora
		ORHY	Oryzopsis hymenoides
		SIHY	Sitanion hystrix
		STCO4	Stipa comata
		AMGR	Amaranthus graecizans
		ARIN4	Argemone intermedia
		ARDR4	Artemisia dracunculoides
		ARLU	Artemisia ludoviciana
			Asclepias hallii
		ASPU	Asclepias pumila
		ASSP	Asclepias speciosa
		CHAL7	Chenopodium album
		*CHGR2	Chenopodium incisum
		CHLE4	Chenopodium leptophyllum
		CIUN	Cirsium undulatum
		CLSE	Cleome serrulata
		DYPA	Dyssodia papposa
		ERDI4	Erigeron divergens
		ERPU2	Erigeron pumilus
		EUGL3	Euphorbia glyptosperma
		EVNU	Evolvulus nuttallianus
		GACO5	Gaura coccinea
		GILA3	Gilia laxiflora
		GRSQ	Grindelia squarrosa
		HASP2	Haplopappus spinulosus
		HELIA3	Helianthus sp.
			Heterotheca villosa
		HYAR2	Hymenopappus arenosus
		HYFI	Hymenopappus filifolius
		*HYFIL	Hymenopappus lugens
		IVAX	Iva axillaris
		KOSC	Kochia scoparia
		LIPU	Liatris punctata
		LYJU	Lygodesmia juncea
		MEOF	Melilotus officinalis
		MILI3	Mirabilis linearis
		OEAL	Oenothera albicaulis
		OECO2	Oenothera coronopifolia
		OEST2	Oenothera strigosa
		OENOT	Oenothera sp.
		ORLU	Orobanche ludoviciana
		*PECA11	Petalostemon candidum
		PSTE3	Psoralea tenuiflora
		RACO3	Ratibida columnifera
		RAPE3	Ratibida peduncularis

Appendix Table IV.10. (Continued)

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
		SAKA	Salsola kali
		SCBR3	Scutellaria brittoni
		SEMU2	Senecio multicapitatus
		SENEC	Senecio sp.
		SESP3	Senecio spartioides
		SOSE4	Sophora sericea
		STPA4	Stephanomeria pauciflora
		THME	Thelesperma megapotamicum
		VEBR	Verbena bracteata
		ALTE	Allium textile.
		ASBI2	Astragalus bisulcatus
		ASGR3	Astragalus gracilis
		ASPE5	Astragalus pectinatus
		*MATA2	Aster tanacetifolius
		ASTER	Aster sp.
		ASTRA	Astragalus sp.
		BAOP	Bahia oppositifolia
		COPA5	Comandra pallida
		CRMI5	Cryptantha minima
		CRYPT	Cryptantha sp.
		CYAC	Cymopterus acaulis
		CYMOP2	Cymopterus sp.
		DEPI	Descurainia pinnata
		ERBE2	Erigeron bellidiastrum
		LARE	Lappula redowskii
		LEDE	Lepidium densiflorum
		LELU	Lesquerella ludoviciana
		LEMO4	Leucocrinum montanum
		LIIN2	Lithospermum incisum
		LOOR	Lomatium orientale
		LUPU	Lupinus pusillus
		MUDI	Musineon divaricatum
		OXLA3	Oxytropis lambertii
		OXSE	Oxytropis sericea
		PEAL2	Penstemon albidus
		PEAN4	Penstemon angustifolius
		*PLPAG	Plantago purshii
		POAV	Polygonum aviculare
		RUMEX	Rumex sp.
		STAL2	Sisymbrium altissimum
		SETR2	Senecio tridenticulatus
		TAOF	Taraxacum officiniale
		TOGR	Townsendia grandiflora
		*TOEX2	Townsendia sericea
		TROC	Tradescantia occidentalis
		TRPR	Tragapogon pratensis
		VINU2	Viola nuttallii
		ATCA2	Atriplex canescens
		CHNA2	Chrysothamnus nauseosus
		GUSA2	Gutierrizia sarothrae
		YUGL	Yucca glauca
		*MAVI3	Coryphanta vivpara
		OPPO	Opuntia polyacantha
			Parmelia chlorochroa
PA-132	Winter	FESTU	Festuca sp.
		MUHLE	Muhlenbergia sp.
		CAREX	Carex sp.
		JUNIP	Juniperus sp.
		PINUS	Pinus sp.
		PSEUD7	Pseudotsuga sp.
		YUCCA	Yucca sp.
		EUROT	Eurotia sp.
	SPRING	FESTU	Festuca sp.
		POA++	Poa sp.
		AGROP2	Agropyron sp.
		MUHLE	Muhlenbergia sp.

Appendix Table IV.10. (Continued)

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
		STIPA	Stipa sp.
		CAREX	Carex sp.
		JUNIP	Juniperus sp.
		PINUS	Pinus sp.
		PSEUD7	Pseudotsuga sp.
		ATRIP	Atriplex sp.
		CERCO	Cercocarpus sp.
	Summer	FESTU	Festuca sp.
		POA++	Poa sp.
		AGROP2	Agropyron sp.
		MUHLE	Muhlenbergia sp.
		BOUTE	Bouteloua sp.
		CAREX	Carex sp.
		KOCHI	Kochia sp.
			Compositae
		SALIX	Salix sp.
		ATRIP	Atriplex sp.
		RIBES	Ribes sp.
		ROSA+	Rosa sp.
		RHUS+	Rhus sp.
	Fall	FESTU	Festuca sp.
		AGROP2	Agropyron sp.
		MUHLE	Muhlenbergia sp.
		STIPA	Stipa sp.
		BOUTE	Bouteloua sp.
		CAREX	Carex sp.
		POTEN	Potentilla sp.
		LUPIN	Lupinus sp.
		PINUS	Pinus sp.
		PSEUD7	Pseudotsuga sp.
		YUCCA	Yucca sp.
		EUROT	Eurotia sp.
		BERBE	Berberis sp.
		CERCO	Cercocarpus sp.

*Nomenclature or authority change since time of publication.

Appendix Table IV.11. Mule Deer, diet components with composition proportion of 5 percent or greater compiled from scientific information.

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 1 OE	Spring-Summer	Fall	Ref. 11 HS	Winter	Summer	Ref. 13 FA	Summer	Ref. 15 OE	Winter	Ref. 16 FA	Summer	Ref. 17 FA	Spring-Summer	Fall-Winter	Ref. 18 FA	Winter	Ref. 23 BC	Summer (Tame deer)	Ref. 25 RA	Spring-Summer	Fall-Winter	Ref. 26 FA	1977-78	Ref. 33 RA	December	Ref. 58 RA	Year	April-Sept.	October-March	Ref. 66 FA	Summer	Ref. 68 RA	Spring-Summer	Fall-Winter	Ref. 69 OE	Summer	Ref. 91 BC	Winter	Ref. 93	Cliffrose, Juniper-sagebrush	Juniper-sagebrush-bitterbrush	Oak-sagebrush-grass	Pinyon-sage-bitterbrush	SCS PLANT CODE
	TOTAL GRASSES						44	11				31									18									16	5	37											70	25	58	9	
DAUN	Danthonia unispicata	C_3*		8	24																																										DAUN
KOCR	Koeleria cristata	C_3			26																																										KOCR
SIHY	Sitanion hystrix	C_3		10																																											SIHY
AGSP	Agropyron spicatum	C_3			10																																				43						AGSP
POSE	Poa secunda	C_3			34																																										POSE
POA++	Poa sp.	C_3														7					8																										POA++
FESTU	Festuca sp.	C_3														10																															FESTU
	Graminere (Green grass)																													13		32															
STPI2	Stipa pinetorum	C_3*																																							6						STPI2
BRTE	Bromus tectorum	C_3																																									31	17			BRTE
BOUTE	Bouteloua sp.	C_4																																													BOUTE
	Gramineae sp.																									9																					
	Unidentified grasses																																														

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 1 OE	Spring-Summer	Fall	Ref. 11 HS	Winter	Summer	Ref. 13 FA	Summer	Ref. 15 OE	Winter	Ref. 16 FA	Summer	Ref. 17 FA	Spring-Summer	Fall-Winter	Ref. 18 FA	Winter	Ref. 23 BC	Summer (Tame deer)	Ref. 25 RA	Spring-Summer	Fall-Winter	Ref. 26 FA	1977-78	Ref. 33 RA	December	Ref. 58 RA	Year	April-Sept.	October-March	Ref. 66 FA	Summer	Ref. 68 RA	Spring-Summer	Fall-Winter	Ref. 69 OE	Summer	Ref. 91 BC	Winter	Ref. 93	Cliffrose, Juniper-sagebrush	Juniper-sagebrush-bitterbrush	Oak-sagebrush-grass	Pinyon-sage-bitterbrush	SCS PLANT CODE
	TOTAL FORBS											13									48		23							14	19	11				32	22		18					6	21	10	
ARCO9	Arnica cordifolia	C_3*																																													ARCO9
BASE2	Balsamorhiza serrata	C_3*		5																																											BASE2
CAQU2	Camassia quamash			19																																											CAQU2
LOLE	Lomatium leptocarpum			7																																											LOLE
SIOR	Sidalcea oregana			23																																											SIOR
LUPIN	Lupinous sp.	C_3*																																													LUPIN
BRODI	Brodiaea sp.	C_3*					12																																								BRODI
ERBO	Erodium botrys						7																																								ERBO
ERCI6	Erodium circutarium						7																																								ERCI6
LOTUS	Lotus sp.						5																																								LOTUS
SOMI2	Solidago missouriensis	C_4																																													SOMI2
PLAGI	Plagiobothrys sp.						6																																								PLAGI
POTEN	Potentilla sp.	C_4*																																													POTEN
ARFR4	Artemisia frigida	C_3														5	9																														ARFR4
ERIGE2	Erigeron sp.															5																															ERIGE2
GEFR2	Geranium fremontii																				6																										GEFR2
ERIAS	Eriastrum sp.																						5																								ERIAS
EUPHO	Euphorbia sp.	C_4*																					11																								EUPHO
EUSE6	Euphorbia serrula	C_4																																													EUSE6
MENOD	Menodora sp.																																														MENOD
VEWO2	Veronica wormskjoldii																																														VEWO2
ERSU3	Erigeron superbus																																														ERSU3
ERSP4	Erigeron speciosus	C_3																																													ERSP4
LINUM	Linum sp.	C_3*																																		9										LINUM
ASTRA	Astragalus sp.	C_3*																																				5								ASTRA
TAOF	Taraxacum officinale	C_3																																				9								TAOF
	Phlox bryoides	C_3*																																						9						
LASE	Lactuca serriola	C_4																																													LASE
LOMAT	Lomatium sp.	C_3*																																													LOMAT
MESA	Medicago sativa	C_3																																													MESA
MEOF	Melilotus officinalis	C_3																																													MEOF
SOSPN	Solidago decumbens	C_4*																																													SOSPN
ASCH2	Aster chilensis	C_4*																																													ASCH2
FRVIO	Fragaria ovalis																																														FRVIO
TRLO	Trifolium longipes	C_3*																																													TRLO
	Unknown forbs							18																							7					13	7										

Appendix Table IV.11 (Continued)

SCS PLANT CODE	Ref. 102 RA	Summer	Fall	Winter	Spring	Ref. 131 RA	Summer	Late summer	Winter	Spring	Ref. 132 FA	Winter	Spring	Summer	Fall	Ref. 133 CP & OE	Winter	Ref. 135 FA	March-July	Ref. 136 BC	Summer	Clearcut Forest	Dry Meadow	Wet Meadow	Mature Forest	Stagnant Forest	SCS PLANT CODE
					17		9					5	17				7										
DAUN																											DAUN
KOCR																											KOCR
SIHY																											SIHY
AGSP																											AGSP
POSE																											POSE
POA++																											POA++
FESTU																											FESTU
STPI2																											STPI2
BRTE																											BRTE
BOUTE							9																				BOUTE
					17																						

SCS PLANT CODE	Ref. 102 RA	Summer	Fall	Winter	Spring	Ref. 131 RA	Summer	Late summer	Winter	Spring	Ref. 132 FA	Winter	Spring	Summer	Fall	Ref. 133 CP & OE	Winter	Ref. 135 FA	March-July	Ref. 136 BC	Summer	Clearcut Forest	Dry Meadow	Wet Meadow	Mature Forest	Stagnant Forest	SCS PLANT CODE
		54	16	40	24		18	25	17			5	8	8	20		29										
ARCO9																									24	37	ARCO9
BASE2																											BASE2
CAQU2																											CAQU2
LOLE																											LOLE
SIOR																											SIOR
LUPIN															7		5										LUPIN
BROO1																											BROO1
ERBO																											ERBO
ERCI6																											ERCI6
LOTUS																											LOTUS
SOMI2																											SOMI2
																	6										
PLAGI																											PLAGI
POTEN															6												POTEN
ARFR4																	9										ARFR4
ERIGE2																											ERIGE2
GEFR2																											GEFR2
ERIAS																											ERIAS
EUPHO																											EUPHO
EUSE6							15	24	5																		EUSE6
MENOD									10																		MENOD
VEWO2																											VEWO2
																							6				
ERSU3																									6		ERSU3
ERSP4																								18			ERSP4
LINUM																											LINUM
ASTRA																											ASTRA
TAOF																						36	34	28			TAOF
LASE		5																									LASE
LOMAT					12																						LOMAT
MESA		5																									MESA
MEOF																											MEOF
		27																									
SOSPN																						32					SOSPN
ASCH2																						8	11				ASCH2
FRVIO																						5			5		FRVIO
TRLO																							8				TRLO

+ Provisional photosynthetic pathway assignment

Appendix Table IV.11. Mule Deer, diet components with composition proportion of 5 percent or greater compiled from scientific information.

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAYS	Ref. 1 OC	Spring-Summer	Fall	Ref. 11 HS	Winter	Summer	Ref. 13 FA	Summer	Ref. 15 OC	Winter	Ref. 16 FA	Summer	Ref. 17 FA	Spring-Summer	Fall-Winter	Ref. 18 FA	Winter	Ref. 23 BC	Summer (Tame deer)	Ref. 25 RA	Spring-Summer	Fall-Winter
	TOTAL SHRUBS						17	85				56									32		52	48
SYAL	Symphoricarpos albus																							
VASC	Vaccinium scoparium																							
ROSA	Rosa sp.	C_4*																						
DALEA	Dalea sp.	C_4																						
CAER	Calliandra eriophylla																							
CECO	Ceanothus cordulatus							44																
HAPA6	Haplopappus parryi																							
ASMI0*	Astragalus decumbens	C_3*																						
KRPA	Krameria parvifolia	C_4*																						
RIBES	Ribes sp.							8																
GERI	Geranium richardsonii																							
MECI3	Mertinsa ciliata																							
ARMA2	Arctostaphylos mariposa						8																	
ACCO4	Aconitum columbianum																							
FERU	Fendlera rupicola																							
CEMO4	Cercocarpus betuloides									20														
NOMI	Nolina microcarpa																							
CERE2	Celtis reticulata																							
ERIOG	Eriogonum sp.	C_4*																						
EYPO	Eysenhardtia polystachya																							
PSME	Pseudotsuga menziesii																							
BERE	Berberis repens																							
CELE3	Cercocarpus ledifolius																							
ARTEM	Artemisia sp.																							
QUDO	Quercus douglasii																							
AMELA	Amelanchier sp.																							
PUTR2	Purshia tridentata																							
PAMY	Pachystima myrsinites																							
QUERC	Quercus sp.																							
ADFA	Adenostoma fasciculatum																							
QUDU	Quercus dumosa																							
QUKE	Quercus kelloggii																							
QUUN	Quercus undulata																							
SYMPH	Symphoricarpus sp.																							
PRJUG	Prosopis glandulosa																							
JUNIP	Juniperus sp.	C_3*												14		5	5							
CEMO2	Cercocarpus montanus															33	26				5			
PSEUD7	Pseudotsuga sp.																							
CHVI8	Chrysothamnus viscidiflorus	C_4*																						
CHRYS9	Chrysothamnus sp.	C_4*																						
CHNA2	Chrysothamnus nauseosus	C_4																						
JUCO6	Juniperus communis	C_3*																						
PINUS	Pinus sp.																							
CEMO2*	Cercocarpus breviflorus																							
YUCCA	Yucca sp.	C_3*																						
RHTR	Rhus trilobata	C_3*																						
AMAL2	Amelanchier alnifolia	C_3*																						
SHAR	Shepherdia argentea																							
SHCA	Shepherdia canadensis																							
	Artemisia tridentata wyomingensis	C_3*																						
ARCA13	Artemisia cana																							
PRVI3	Prunus virginiana																							
ACACI	Acacia sp.																							
RHVI3	Rhus virens	C_3*																						
RHMI3	Rhus microphylla	C_3*																						
PORLI	Porlieria angustifolia																							

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAYS	Ref. 26 FA	1977-78	Ref. 33 RA	December	Ref. 58 RA	Year	April-Sept.	October-March	Ref. 66 FA	Summer	Ref. 68 RA	Spring-Summer	Fall-Winter	Ref. 69 OC	Summer	Ref. 91 BC	Winter	Ref. 93	Cliffrose, Juniper-sagebrush	Juniper-sagebrush-bitterbrush	Oak-sagebrush-grass	Pinyon-sage-bitterbrush	SCS PLANT CODE
	TOTAL SHRUBS							70	76	52				65	76		80				28	69	21	81	
SYAL	Symphoricarpos albus																6								SYAL
VASC	Vaccinium scoparium																								VASC
ROSA	Rosa sp.	C_4*															42								ROSA
DALEA	Dalea sp.	C_4																							DALEA
CAER	Calliandra eriophylla																								CAER
CECO	Ceanothus cordulatus																								CECO
HAPA6	Haplopappus parryi																								HAPA6
ASMI0*	Astragalus decumbens	C_3*																							ASMI0*
KRPA	Krameria parvifolia	C_4*																							KRPA
RIBES	Ribes sp.																								RIBES
GERI	Geranium richardsonii																								GERI
MECI3	Mertinsa ciliata																								MECI3
ARMA2	Arctostaphylos mariposa																								ARMA2
ACCO4	Aconitum columbianum																								ACCO4
FERU	Fendlera rupicola																								FERU
CEMO4	Cercocarpus betuloides																								CEMO4
NOMI	Nolina microcarpa																								NOMI
CERE2	Celtis reticulata																								CERE2
ERIOG	Eriogonum sp.	C_4*																							ERIOG
EYPO	Eysenhardtia polystachya																								EYPO
PSME	Pseudotsuga menziesii			24																					PSME
BERE	Berberis repens			14																					BERE
CELE3	Cercocarpus ledifolius			11		7																			CELE3
ARTEM	Artemisia sp.					14																			ARTEM
QUDO	Quercus douglasii								6																QUDO
AMELA	Amelanchier sp.					6																			AMELA
PUTR2	Purshia tridentata					7																			PUTR2
PAMY	Pachystima myrsinites					6																			PAMY
QUERC	Quercus sp.							17	9	18															QUERC
ADFA	Adenostoma fasciculatum							10	12	12															ADFA
QUDU	Quercus dumosa							10	9	5															QUDU
QUKE	Quercus kelloggii							6	8																QUKE
QUUN	Quercus undulata													27	13										QUUN
SYMPH	Symphoricarpus sp.																								SYMPH
PRJUG	Prosopis glandulosa																								PRJUG
JUNIP	Juniperus sp.	C_3*												5	19										JUNIP
CEMO2	Cercocarpus montanus					16																			CEMO2
PSEUD7	Pseudotsuga sp.																								PSEUD7
CHVI8	Chrysothamnus viscidiflorus	C_4*																							CHVI8
CHRYS9	Chrysothamnus sp.	C_4*																							CHRYS9
CHNA2	Chrysothamnus nauseosus	C_4																							CHNA2
JUCO6	Juniperus communis	C_3*																							JUCO6
PINUS	Pinus sp.																								PINUS
CEMO2*	Cercocarpus breviflorus													8	17										CEMO2*
YUCCA	Yucca sp.	C_3*												9	10										YUCCA
RHTR	Rhus trilobata	C_3*												6	5										RHTR
AMAL2	Amelanchier alnifolia	C_3*															15								AMAL2
SHAR	Shepherdia argentea																								SHAR
SHCA	Shepherdia canadensis																6								SHCA
	Artemisia tridentata wyomingensis	C_3*																	13						
ARCA13	Artemisia cana																								ARCA13
PRVI3	Prunus virginiana																								PRVI3
ACACI	Acacia sp.																								ACACI
RHVI3	Rhus virens	C_3*																							RHVI3
RHMI3	Rhus microphylla	C_3*																							RHMI3
PORLI	Porlieria angustifolia																								PORLI

Appendix Table IV.11. (Continued)

SCS PLANT CODE	Ref. 102 RA	Summer	Fall	Winter	Spring	Ref. 131 RA	Summer	Late summer	Winter	Spring	Ref. 132 FA	Winter	Spring	Summer	Fall	Ref. 133 CP & OE	Winter	Ref. 135 FA	March-July	Ref. 136 BC	Summer	Clearcut Forest	Dry Meadow	Wet Meadow	Mature Forest	Stagnant Forest	SCS PLANT CODE
		43	81	60	59		34	36	16	10		90	75	91	76		62										
SYAL																											SYAL
VASC																									22	22	VASC
ROSA		9	7											7													ROSA
DALEA							9	6																			DALEA
CAER																			10								CAER
CECO																											CECO
HAPA6																										8	HAPA6
ASMID*																										10	ASMID*
KRPA																			17								KRPA
RIBES													10														RIBES
GERI																								6			GERI
HECI3																								11			HECI3
ARMA2																											ARMA2
ACCO4																								11			ACCO4
FERU																			6								FERU
CEMOA																											CEMOA
NOMI																			5								NOMI
CERE2																			9								CERE2
ERIOG																			5								ERIOG
EYPO																			13								EYPO
PSME																											PSME
BERE																											BERE
CELE3																											CELE3
ARTEM												36	33		11												ARTEM
QUDO																											QUDO
AMELA																											AMELA
PUTR2																											PUTR2
PAMY																											PAMY
QUERC																											QUERC
ADFA																											ADFA
QUDU																											QUDU
QUKE																											QUKE
QUUN																											QUUN
SYMPH		9	27																								SYMPH
PRJUG							5																				PRJUG
JUNIP				10	41							12	5		10												JUNIP
CEMO2																											CEMO2
PSEUD7												7			7												PSEUD7
CHVI8																	7										CHVI8
CHRYS9															11												CHRYS9
CHNA2			14	33																							CHNA2
JUCO6					6												8										JUCO6
PINUS												7	7														PINUS
CEMO2*																											CEMO2*
YUCCA																											YUCCA
RHTR			15																								RHTR
AMAL2																											AMAL2
SHAR		15																									SHAR
SHCA																											SHCA
ARCAI3			7		6																						ARCAI3
PRVI3		5																									PRVI3
ACACI							8	8																			ACACI
RHVI3									9	6																	RHVI3
RHMI3							11																				RHMI3
PORLI								9	5																		PORLI

* Nomenclature or authority change since time of publication
\+ Provisional photosynthetic pathway assignment

Appendix Table IV.11. Mule Deer, diet components with composition proportion of 5 percent or greater compiled from scientific information.

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 1 OC	Spring-Summer	Fall	Ref. 11 MS	Winter	Summer	Ref. 13 FA	Summer	Ref. 15 OC	Winter	Ref. 16 FA	Summer	Ref. 17 FA	Spring-Summer	Fall-Winter	Ref. 18 FA	Winter	Ref. 23 BC	Summer (Tame deer)	Ref. 25 AA	Spring-Summer	Fall-Winter	Ref. 26 FA	1977-78	Ref. 33 AA	December	Ref. 58 AA	Year	April-Sept.	October-March	Ref. 66 FA	Summer	Ref. 68 AA	Spring-Summer	Fall-Winter	Ref. 69 OC	Summer	Ref. 91 BC	Winter	Ref. 93	Cliffrose, Juniper-sagebrush	Juniper-sagebrush-bitterbrush	Oak-sagebrush-grass	Pinyon-sage-bitterbrush	SCS PLANT CODE
	SHRUBS (cont.)																																														
QUWI	Quercus wislizenii						8																							5	8																QUWI
STPA4	Stephanomeria pauciflora	C_4																																													STPA4
ATRIP	Atriplex sp.																																														ATRIP
SALIX	Salix sp.									18																																					SALIX
ARTR2	Artemisia tridentata	C_3														23	34		8															41													ARTR2
AMUT	Amelanchier utahensis	C_3*								43				52					5																												AMUT
PIED	Pinus edulis									5				18		6	14		54															6													PIED
PURSH	Purshia											43																																			PURSH
	Mahonia repens											8																																			
JUOS	Juniperus osteosperma	C_3																	29																												JUOS
CERCO	Cercocarpus sp.																																	46													CERCO
PIPO	Pinus ponderosa																				13				8																						PIPO
ROAR3	Rosa arkansana	C_4																			8																										ROAR3
PRJU	Prosopis juliflora																						12																								PRJU
ACGR	Acacia greggii																						10	8																							ACGR
CAER	Calliandra eriophylla																						21	26																							CAER
	Other shrubs																																														
	OTHER																											12																			
OPFU	Opuntia fulgida	CAM-C_4*																					10	5																							OPFU
OPEN2	Opuntia engelmannii	CAM-C_4*																					7																								OPEN2
OPSP2	Opuntia spinosior	CAM-C_4*																						6																							OPSP2
ECWI*	Ferocactus wislizeni																							39																							ECWI*
AGLE	Agave lechuguilla																																														AGLE
	Fungi (mushrooms)																																														
	Total cactus																						22	50																							

Appendix Table IV.11. (Continued)

SCS PLANT CODE	Ref. 102 RA	Summer	Fall	Winter	Spring	Ref. 131 RA	Summer	Late summer	Winter	Spring	Ref. 132 FA	Winter	Spring	Summer	Fall	Ref. 133 CP & OE	Winter	Ref. 135 FA	March-July	Ref. 136 BC	Summer	Clearcut Forest	Dry Meadow	Wet Meadow	Mature Forest	Stagnant forest	SCS PLANT CODE
QUWI																											QUWI
STPA4																			7								STPA4
ATRIP												13			10												ATRIP
SALIX														75	6												SALIX
ARTR2				7													30										ARTR2
AMUT																											AMUT
PIED																											PIED
PURSH																											PURSH
JUOS																											JUOS
CERCO												16			5												CERCO
PIPO																											PIPO
ROAR3																											ROAR3
PRJU																			5								PRJU
ACGR																			7								ACGR
CAER																											CAER
				5										5	9												

SCS PLANT CODE	Ref. 102 RA	Summer	Fall	Winter	Spring	Ref. 131 RA	Summer	Late summer	Winter	Spring	Ref. 132 FA	Winter	Spring	Summer	Fall	Ref. 133 CP & OE	Winter	Ref. 135 FA	March-July	Ref. 136 BC	Summer	Clearcut Forest	Dry Meadow	Wet Meadow	Mature Forest	Stagnant forest	SCS PLANT CODE
							22	26	55	71																	
OPFU																											OPFU
OPEN2							19	9	13	23																	OPEN2
OPSP2																											OPSP2
ECWI*																											ECWI*
AGLE								17	42	48																	AGLE
																							7		15	14	

* Nomenclature or authority change since time of publication

\+ Provisional photowynthetic pathway assignment

Appendix Table IV.12. Mule Deer, additional diet components with composition proportion of less than 5 percent compiled from the scientific literature.

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
MD- 1	Spring/Summer	CAGE2	Carex geyeri
		KOCR	Koeleria cristata
		ADBI	Adenocaulon bicolor
		PODO4	Polygonum douglasii
		ARCO9	Arnica cordifolia
		GETR	Geum triflorum
		LONU2	Lomatium nudicaule
		LUPIN	Lupinus sp.
		MINU	Microseris nutans
		SPBE2	Spiraea betutlfolia
		SYAL	Symphoricarpos albus
		VAME	Vaccinium membranaceum
		VASC	Vaccinium scoparium
		ROSA+	Rosa sp.
		RILA	Ribes lacustre
	Fall	CAGE2	Carex geyeri
		CARU	Calamagrostis rubens
		SPBE2	Spiraea betulifolia
		SYAL	Symphoricarpos albus
		VAME	Vaccinium membranaceum
		VASC	Vaccinium scoparium
		PAMY	Pachystima myrsinites
		CHUM	Chimaphila umbellata
			Unidentified Forbs
MD- 9	Winter	PURSH	Purshia sp.
		STCO6	Streptanthus cordatus
	Summer	JUNIP	Juniperus sp.
MD- 11	Winter	ERBO	Erodium botrys
		MOPE2	Montia perfoliata
		TRIFO	Trifolium sp.
		AECA	Aesculus californica
		CECU	Ceanothus cuneatus
		*CEMO2	Cercocarpos betuloides
		SYMPH	Symphoricarpos sp.
	Summer	COLLI	Collinsia sp.
		GAYOP	Gayophytum sp.
		PHACE	Phacelia sp.
		ABCO	Abies concolor
		ARPA6	Arctostaphylos patula
		CHFO	Chamaebatia foliosa
		PREM	Prunus emarginata
		SYMPH	Symphoricarpos sp.
MD- 13		CAREX	Carex sp.
		STIPA	Stipa sp.
		AGROP2	Agropyron sp.
		EULA5	Eurotia lanata
		KOCR	Koeleria cristata
		BROMU	Bromus sp.
		ORHY	Oryzopsis hymenoides
MD- 15		WYAM	Wyethia amplexicaulis
		ARAR8	Artemisia arbuscula
			Pacific aster
MD- 16		LESQU	Lesquerella sp.
		BERBE	Berberis sp.
		ARTR2	Artemisia tridentata
		CEMO2	Cercocarpus montanus
		SYMPH	Symphoricarpos sp.
		MERTE	Mertensia sp.
		CHRYS9	Chrysothamnus sp.
		QUGA	Quercus gambelii
		EULA5	Eurotia lanata
		CAREX	Carex sp.
		STCO4	Stipa comata
		AGROP2	Agropyron sp.
		ORHY	Oryzopsis hymenoides
		FESTU	Festuca sp.
		KOCR	Koeleria cristata
		BROMU	Bromus sp.
		POA++	Poa sp.

Appendix Table IV.12. (Continued)

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
MD- 18		PUTR2	Purshia tridentata
		MESA	Medicago sativa
		AGROP2	Agropyron sp.
		QUGA	Quercus gambelii
		CEMO2	Cercocarpus montanus
		CAREX	Carex sp.
			Compositae
		STCO4	Stipa comata
		ARFR4	Artemisia frigida
		DESCU	Descurainia sp.
		LEMO3	Lesquerella montana
MD- 22		STIPA	Stipa sp.
		BROMU	Bromus sp.
		DANTH	Danthonia sp.
		FESTU	Festuca sp.
		CAREX	Carex sp.
		EULA5	Eurotia lanata
		PUTR2	Purshia tridentata
		JUNIP	Juniperus sp.
MD- 23		POHI6	Potentilla hippiana
		PULU	Pulsatilla ludoviciana
		ARFR4	Artemisia frigida
		*FRVIO	Frageria ovalis
		BRIN2	Bromus inermis
		CAHE5	Carex heliophila
		TAOF	Taraxacum officinale
		OENOT	Oenothera sp.
		POTR5	Populus tremulodies
		CHAL7	Chenopodium album
		AGROP2	Agropyron sp.
		PEVI3	Penstemon virens
		COAR4	Convolvulus arvensis
		ERAL4	Eriogonum alatum
		CARO2	Campanula rotundifolia
		ELJU	Elymus junceus
		ARUV	Arctostaphylos uva-ursi
		POPE8	Potentilla pennsylvanica
		SIHY	Sitanion hystrix
		ARVA	Arcenthobium vaginatum
		ANPA4	Antennaria parvifolia
		SEST2	Sedum stenopetalum
		RICE	Ribes cereum
		ANSC2	Andropogon scoparius
		STRO3	Stipa robusta
		KOCR	Koelaria cristata
		TRPO	Tragapogon porrifolius
		POAV	Polygonum aviculare
		ALCE2	Allium cernuum
			Sysimbrium altissimum
		AGAL3	Agrustis alba
		SOTR	Solanum triflorum
		MEOF	Melilotus officinalis
			Fungi (mushrooms)
MD- 25	Fall/Winter	PRJU	Prosopis juliflora
		ACCO2	Acacia constricta
		ERIOG	Eriogonum sp.
		EUPHO	Euphorbia sp.
		EYPO	Eysenhardtia polystachya
			Anisacanthus thurberi
		BAMU	Baileya multiradiata
		CHLI2	Chilopsis linearis
		OPEN2	Opuntia engelmannii
		DEPI	Descurainia pinnata
		VERBE	Verbena sp.
		ERIAS	Eriastrum sp.

Appendix Table IV.12. (Continued)

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
	Spring/Summer	*ECWI	Ferocactus wislizenii
		CHLI2	Chilopsis linearis
		VACA5	Vauquelinia californica
		FOSP2	Fouquieria splendens
		APUN	Apodanthera undulata
		ACCO2	Acacia constricta
		OPSP2	Opuntia spinosior
		BAMU	Baileya multiradiata
		DEPI	Descurainia pinnata
			Anisacanthus thurberi
		VERBE	Verbena sp.
		ERIOG	Eriogonum sp.
**MD- 58	Yearlong	QULO	Quercus lobata
		ERODI	Erodium sp.
		AECA	Aesculus californicus
		RHDI	Rhus diversiloba
			Gramineae (Dry)
		CECU	Ceanothus cuneatus
			Usneaceae
			Pickeringia montana
		MEHI	Medicago hispida
		TRIFO	Trifolium sp.
		ARCTO3	Arctostaphylos sp.
		HEAR5	Heteromeles arbutifolia
		CEIN3	Ceanothus integerrimus
		MALUS	Malus sp.
		*CEMO2	Cercocarpus betuloides
		UMCA	Umbellularia californica
		QUERC	Quercus sp.
		QUGA4	Quercus garryana
		VITIS	Vitis sp.
		BACH	Baeria chrysostoma
			Lotus americanus
		CHPO3	Chlorogalum pomeridianum
			Polypodiaceae
		SILEN	Silene sp.
		VICIA	Vicia sp.
			Agaricaceae
		TRAE	Triticum aestivum
		ARME	Arbutus menziesii
		CEFO	Ceanothus foliosus
			Phoradendron villosum
		ERCA6	Eriodictyon californicum
		QUDU3	Quercus durata
		RHCA	Rhamnus californica
		PYRUS	Pyrus sp.
		POAV	Polygonum aviculare
		ERIOG	Eriogonum sp.
		MELIL	Melilotus sp.
		COAR4	Convolvulus arvensis
		CIRSI	Cirsium sp.
		QUMO2	Quercus morehus
		SALIX	Salix sp.
		RUBUS	Rubus sp.
		RHCR	Rhamnus crocea
		GAFR	Garrya fremonti
		LOIN4	Lonicera interrupta
		PRUNU	Prunus sp.
		RANUN	Ranunculus sp.
			Umbelliferae
		LYHY2	Lythrum hyssopifolia
			Limnanthus douglasii
		POOL	Portulaca oleracea
			Scrophulariaceae
		BRODI	Brodiaea sp.
		LYCOP2	Lycopodium sp.
		HYGL2	Hypochoeris glabra
		NIBI	Nicotiana biglovii
		TRIEN	Trientalis
		STME2	Stellaria media

Appendix Table IV.12. (Continued)

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
MD- 66	Spring/Summer	CAREX	Carex sp.
		LESQU	Lesquerella sp.
		PETRO	Petrophytum sp.
		CHRYS9	Chrysothamnus sp.
		BOGR2	Bouteloua gracilis
		ASTRA	Astragalus sp.
		BERE	Berberis repens
		LEMO4	Leucocrinum montanum
		STIPA	Stipa sp.
		AGSM	Agropyron smithii
		MUHLE	Muhlenbergia sp.
		ANTEN	Antennaria sp.
		DESCU	Descurainia sp.
		KOSC	Kochia scoparia
		LATHY	Lathyrus sp.
		LEPID	Lepidium sp.
		MESA	Medicago sativa
		OPUNT	Opuntia sp.
	Fall/Winter	CHRYS9	Chrysothamnus sp.
		BROMU	Bromus sp.
		FESTU	Festuca sp.
		AGSM	Agropyron smithii
		POA++	Poa sp.
		ATRIP	Atriplex sp.
		EULA5	Eurotia lanata
		KOSC	Kochia scoparia
		LATHY	Lathyrus sp.
		SPORO	Sporobolus sp.
		STIPA	Stipa sp.
		BERE	Berberis repens
		LESQU	Lesquerella sp.
		OPUNT	Opuntia sp.
		SHEPH	Shepherdia sp.
MD- 68	Spring/Summer	EUPHO	Euphorbia sp.
		DYPA	Dyssodia papposa
		ARLU	Artemisia ludoviciana
			Acanthaceae
		JUGLA	Juglans sp.
		SPHAE	Sphaeralcea sp.
		MELE2	Melampodium leucanthus
		VEWR	Verbena wrightii
		TRIFO	Trifolium sp.
		NOLIN	Nolina sp.
		FAPA	Fallugia paradoxa
		*BEHA	Mahonia haematocarpa
			Lichen
		STBA	Stenandrium barbatum
		SAKA	Salsola kali
		OSKN	Ostrya knowltonii
		VIGUI	Viguiera sp.
		GARRY	Garrya sp.
			Crassulaceae
		ERHA	Eriogonum havardii
		CHENO	Chenopodium sp.
		CLEMA	Clematis sp.
		AMELA	Amelanchier sp.
		HECO	Hedeoma costatum
			Cruciferae
		CHORI2	Chorizanthe sp.
		PIED	Pinus edulis
		SYMPH	Symphoricarpos sp.
		ACACI	Acacia sp.
		TEUCR	Teucrium sp.
		GUTIE	Gutierrezia sp.
		CEGR	Ceanothus greggii
		ATCA2	Atriplex canescens
		AGAVE	Agave sp.

Appendix Table IV.12. (Continued)

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
		PHJU	Phoradendron juniperinum
		DAFO	Dalea formosa
		PROSO	Prosopis sp.
		ARTE	Arbutus texana
		PTAN	Ptelea angustifolia
		LINUM	Linum sp.
		COTI3	Coreopsis tinctoria
		THALS	Thlaspi sp.
		LEFE	Lesquerella fendleri
			Liliaceae
	Fall/Winter	GARRY	Garrya sp.
			Lichen
		GUTIE	Gutierrezia sp.
		PIED	Pinus edulis
		MELE2	Melampodium leucanthus
		COTI3	Coreopsis tinctoria
		OPUNT	Opuntia sp.
		NOLIN	Nolina sp.
		FAPA	Fallugia paradoxa
		VEWR	Verbena wrightii
		THLAS	Thlaspi sp.
		LEFE	Lesquerella fendleri
		CEGR	Ceanothus greggii
		AGAVE	Agave sp.
		ATCA2	Atriplex canescens
			Cruciferae
			Liliaceae
		DAFO	Dalea formosa
		PROSO	Prosopis sp.
		ARCA14	Artemisia carruthii
		EUPHO	Euphorbia sp.
		SPHAE	Sphaeralcea sp.
		VIGUI	Viguiera sp.
		TEUCR	Teucrium sp.
		ERHA	Eriogonum havardii
		CHENO	Chenopodium sp.
MD- 69	Summer	POTR5	Populus tremuloides
		SPLU	Spiraea lucida
		SALIX	Salix sp.
		PSME	Pseudotsuga menziesii
			Fragaria glauca
		ASTER	Aster sp.
MD- 91		AGSM	Agropyron smithii
		POFE	Poa fendleriana
		AMAL2	Amelanchier alnifolia
		SYOR2	Symphoricarpus oreophilus
		CHVI8	Chrysothamnus viscidiflorus
		BOGR2	Bouteloua gracilis
		ARFR2	Artemisia frigida
MD-102	Summer	ASGI5	Astragalus gilviflorus
		GLLE3	Glycyrrhiza lepidota
		OXYTR	Oxytropis sp.
		YUGL	Yucca glauca
		CHNA2	Chrysothamnus nauseosus
		COST4	Cornus stolonifera
		PRVI	Prunus virginiana
		RHTR	Rhus trilobata
		RIAU	Ribes aureum
	Fall	ASGI5	Astragalus gilviflorus
		GLLE3	Glycyrrhiza lepidota
		MEDIC	Medicago sp.
		OXYTR	Oxytropis sp.
		COST4	Cornus stolonifera
		JUNIP	Juniperus sp.
		JUCO6	Juniperus communis
		RIAU	Ribes aureum
		SHAR	Shepherdia argentea

Appendix Table IV.12. (Continued)

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
	Winter	ERMU3	Eriogonum multiceps
		MEOF	Melilotus officinalis
		OXYTR	Oxytropis sp.
		ARCA13	Artemisia cana
		JUCO6	Juniperus communis
		RHTR	Rhus trilobata
		ROSA+	Rosa sp.
		SYMPH	Symphoricarpus sp.
	Spring	ERMU3	Eriogonum multiceps
		OXYTR	Oxytropis sp.
		ARTR2	Artemisia tridentata
		CHNA2	Chrysothamnus nauseosus
MD-131	Summer	RHVI3	Rhus virens
		PRJUG	Prosopis glandulosa
		DYSSO	Dyssodia sp.
		NOER	Nolina erumpens
		FOAN	Foresteria angustifolia
		VIGUI	Viguiera sp.
		ERDI4	Erigeron divergens
		MENOD	Menodora sp.
		*HOUST	Hedyotis sp.
		AGLE	Agave lecheguilla
	Late Summer	QUERC	Quercus sp.
		RHMI3	Rhus microphylla
		PRJUG	Prosopis glandulosa
		RHUS+	Rhus sp.
		CERCO	Cercocarpus sp.
		DYSSO	Dyssodia sp.
		DITE3	Diospyros texana
		FOAN	Foresteria angustifolia
		VIGUI	Viguieria sp.
		JUNIP	Juniperus sp.
			Xanthocephalum sp.
		PRHA	Prunus havardii
		HOFFM	Hoffmanseggia sp.
		ERDI4	Erigeron divergens
		MENOD	Menodora sp.
		BAHIA	Bahia sp.
		ECHIN3	Echinocereus sp.
	Winter	POAN4	Poblieria angustifolia
		RHMI3	Rhus microphylla
		DALEA	Dalea sp.
		ERDI4	Erigeron divergens
	Spring	ACACI	Acacia sp.
		POAN4	Porlieria angustifolia
		RHUS+	Rhus sp.
		RHTR	Rhus trilobata
		PHORA	Phoradendron sp.
		VIGUI	Viguiera sp.
		LEUCO3	Leucophyllum sp.
		EUSE6	Euphorbia serrula
		VERBE	Verbena sp.
		ARTEM	Artemesia sp.
		KRPAG	Krameria glandulosa
MD-132	Winter	FESTU	Festuca sp.
		MUHLE	Muhlenbergia sp.
		CAREX	Carex sp.
		YUCCA	Yucca sp.
		EUROT	Eurotia sp.
		CHRYS9	Chrysothamnus sp.
	Spring	FESTU	Festuca sp.
		MUHLE	Muhlenbergia sp.
		POA++	Poa sp.
		AGROP2	Agropyron sp.
		STIPA	Stipa sp.

Appendix Table IV.12. (Continued)

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
		CAREX	Carex sp.
		ELEOC	Eleocharis sp.
		JUNCU	Juncus sp.
		POTEN	Potentilla sp.
		PSEUD7	Pseudotsuga sp.
		SALIX	Salix sp.
		ATRIP	Atriplex sp.
		CHRYS9	Chrysothamnus sp.
	Summer	FESTU	Festuca sp.
		POA++	Poa sp.
		AGROP2	Agropyron sp.
		MUHLE	Muhlenbergia sp.
		BOUTE	Bouteloua sp.
		CAREX	Carex sp.
		KOCHI	Kochia sp.
		ERIOG	Eriogonum sp.
		POTEN	Potentilla sp.
			Compositae
		ATRIP	Atriplex sp.
		RIBES	Ribes sp.
		CERCO	Cercocarpus sp.
		RHUS+	Rhus sp.
		CHRYS9	Chrysothamnus sp.
		ARTEM	Artemisia sp.
	Fall	FESTU	Festuca sp.
		POA++	Poa sp.
		AGROP2	Agropyron sp.
		MUHLE	Muhlenbergia sp.
		STIPA	Stipa sp.
		BOUTE	Bouteloua sp.
		CAREX	Carex sp.
		PINUS	Pinus sp.
		YUCCA	Yucca sp.
		EUROT	Eurotia sp.
		BERBE	Berberis sp.
MD-133		AGSP	Agropyron spictaum
		AGSU	Agropyron subsecundum
		CARU	Calamagrostis rubescens
		CAREX	Carex sp.
		FEID	Festuca idahoensis
		POA++	Poa sp.
		ACMI2	Achillea millefolium
		ARMI4	Artemisia michauxiana
		ERIGE2	Erigeron sp.
		PHHO	Phlox hoodii
		TRDU	Tragapogon dubius
		TRIFO	Trifolium sp.
			Cornus stolonifera
		JUSC2	Juniperus scopulorum
		PICO	Pinus contorta
		PIFL2	Pinus flexilis
		POTR5	Populus tremuloides
		PRVI	Prunus virginiana
		PSME	Pseudotsuga menzieii
		RIBES	Ribes sp.
		ROAC	Rosa acicularis
		SALIX	Salix sp.
		SHCA	Shepherdia canadensis
		TECA2	Tetradymia canescens
MD-135		QUOB	Quercus oblongifolia
		MIDY	Mimosa dysocarpa
		ARPL2	Argemone platyceras
		FOSP2	Fouquieria splendens
		JUMO	Juniperus monosperma
		ANTH2	Anisocanthus thurberi
		BOCH	Bouteloua chondrosioides
		BOCU	Bouteloua curtipendula
MD-136	Clearcut Forest	ARCO9	Arnica cordifolia

*Nomenclature or authority change since time of publication

**Reference is for Black-tailed Deer

Appendix Table IV.13. White Tail Deer, diet components with composition proportion of 5 percent or greater compiled from the scientific literature.

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 31 RA	Spring 1970-71	Ref. 32 RA	1972-74	Ref. 131 RA	Summer	Late Summer	Winter	Spring	Ref. 135 FA	March-July	Ref. 137 RA	Summer	Fall	Winter	Spring	SCS PLANT CODE
	TOTAL GRASSES																6	38	
BOUTE	Bouteloua sp.	C_4						12											BOUTE
BOCH	Bouteloua chondrosioides	C_4+											5						BOCH
HORDE	Hordeum sp.	C_3+															5	14	HORDE
	Unidentified grasses																	24	

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 31 RA	Spring 1970-71	Ref. 32 RA	1972-74	Ref. 131 RA	Summer	Late Summer	Winter	Spring	Ref. 135 FA	March-July	Ref. 137 RA	Summer	Fall	Winter	Spring	SCS PLANT CODE
	TOTAL FORBS							21	8	18	12				54	17	29	18	
APRI	Aphanostephus riddellii	C_4+		10		7													APRI
APKI	Aphanostephus kidderi	C_4+				6													APKI
EUSE6	Euphorbia serrula	C_4						19			7								EUSE6
ERO16	Erigeron divergens	C_4								5									ERO16
LOOR2	Lotus oroboides	C_4+								5									LOOR2
ERIOG	Eriogonum sp.	C_4+									5								ERIOG
ERWR	Eriogonum wrightii	C_4+											14						ERWR
MESA	Medicago sativa	C_3													39	7	14		MESA
HELIA3	Helianthus sp.																5		HELIA3
TROV	Tragopogon dubius	C_3																7	TROV
	Unidentified forbs														7			5	

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 31 RA	Spring 1970-71	Ref. 32 RA	1972-74	Ref. 131 RA	Summer	Late Summer	Winter	Spring	Ref. 135 FA	March-July	Ref. 137 RA	Summer	Fall	Winter	Spring	SCS PLANT CODE
	TOTAL SHRUBS							18	60	31	27				45	81	65	43	
POGL9	Prosopis glandulosa			9		6			6										POGL9
ACACI	Acacia sp.								12	7	5								ACACI
QUERC	Quercus sp.								11		8								QUERC
POAN4	Porlieria angustifolia								13										POAN4
GAWR3	Garrya wrightii								11										GAWR3
RHVI3	Rhus virens	C_3+								12	5								RHVI3
RHMI3	Rhus microphylla	C_3+									5								RHMI3
EYPO	Eysenhardtia polystachya												13						EYPO
KRPA	Krameria parvifolia	C_4+											8						KRPA
FERU	Fendlera rupicola												13						FERU
STPA4	Stephanomeria pauciflora	C_4											8						STPA4
NOMI	Nolina microcarpa												9						NOMI
ARPL2	Argemone platyceras	C_4+											5						ARPL2
COST4	Cornus stolonifera														8				COST4
POSA8	Populus sargentii														11	12	16	22	POSA8
SYOC	Symphoricarpos occidentalis														19	55	25	10	SYOC
ARLO7	Artemisia longifolia																12		ARLO7
PSME*	Pseudotsuga taxifolia																6		PSME*
	Unidentified shrubs															8			

Appendix Table IV.13. (Continued)

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 31 RA	Spring 1970-71	Ref. 32 RA	1972-74	Ref. 131 RA	Summer	Late Summer	Winter	Spring	Ref. 135 FA	March-July	Ref. 137 RA	Summer	Fall	Winter	Spring	SCS PLANT CODE
	TOTAL OTHER							24	7	28	49								
	Opuntia lindheimeri var. tricolor			9															
OPLI	Opuntia lindheimeri	C_4-CAM+		7		21													OPLI
OPEN2	Opuntia engelmannii	C_4-CAM+						14		7	21								OPEN2
AGLE	Agave lecheguilla							8		21	28								AGLE
	Unidentified plants			9				25	22	22	10								

* Nomenclature or authority change since time of publication

\+ Provisional photosynthetic pathway assignment

Appendix Table IV.14. White-tailed Deer, additional diet components with composition proportion of less than 5 percent compiled from the scientific literature.

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
WT- 31	Spring		Celtis pallida
		PHVI6	Physalis viscosa
			Condalia obtusifolia
		POAN4	Porlieria angustifolia
		CAIN2	Callirhoe involucrata
		ACGR	Acacia greggii
		BUCE	Bumelia celastrina
		APKI	Aphanostephus kidderi
		OPLE	Opuntia leptocaulis
		PACO11	Parthenium confertum
		DITE3	Diospyros texana
			Castella texana
		ACBE	Acacia berlandieri
		DAAU	Dalea aurea
		LYBE	Lycium berlandieri
		PSGN	Psilostrophe gnaphalodes
		THELE	Thelesperma sp.
		GABR2	Gaura brachycarpa
		ACTO	Acacia tortuosa
		LEGR2	Lesquerella gracilis
		PEDE5	Petalostemum decumbens
		AMPS	Ambrosia psilostachya
		OENOT	Oenothera sp.
		SPPE2	Sphaeralcea pedatifida
		ACRI	Acacia rigidula
			Schaefferia cuneifolia
		ZAFA	Zanthoxylum fagara
		VEPL	Verbena plicata
		*EYAN	Eysenhardtia texana
		DYTE	Dyssodia tenuiloba
		CECI	Cenchrus ciliaris
		CYBA	Cynanchum barbigerum
		MEHE2	Menodora heterophylla
		PLHO	Plantago hookeriana
		ACOB2	Acleisanthes obtusa
		LEFR3	Leucophyllum frutescens
			Condalia hookeri
		SIFI2	Sida filicaulis
			Zornia bracteata
			Schrankia latidens
			Colubrina texensis
		EPAN	Ephedra antisyphlitica
		CATE10	Cassia texana
		COAR4	Convolvulus arvensis
		CITE2	Cirsium texanum
		RHAM	Rhynchosia americana
			Krameria ramosissima
		PRJUG	Prosopis juliflora glandulosa
			Compositae
		ZEHI	Zexmenia hispida
			Setaria firmula
			Cercidium texanum
		PASE5	Paspalum setaceum
		DITE3	Diospyros texana
		YUTR	Yucca treculeana
			Solanaceae
		*RACO3	Ratibida columnaris
		EUPR3	Euphorbia prostrata
		LYBE	Lycium berlandieri
		VERBE	Verbena sp.
		PHIN6	Phyla incisa
		GAPU	Gaillardia pulchella
		CLDR	Clematis drummondii
			Acanthaceae
			Evax verna
		PYMU2	Pyrrhopappus multicaulis
		RUCR	Rumex crispus
		VILE2	Vicia leavenworthii
		ACRA	Acalphya radians
		LIIM	Linum imbricatum
		NOBI2	Nothoscordum bivalve
		PHACE	Phacelia sp.
		POMU2	Portulaca mundula
		ARIST	Aristida sp.
			Prosopis reptans
		*GUTIE	Xanthocephalum sarothrae

Appendix Table IV.14. (Continued)

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
WT- 32		ACGR	Acacia greggii
		BUCE	Bumelia celastrina
			Celtis pallida
		COER	Commelina erecta
		ZAFA	Zanthoxylum fagara
		LAMA2	Lantana macropoda var. albiflora
			Castela texana
		MEHE	Menodora heterophylla
			Colubrina texensis
		XATE	Xanthisma texanum
		PIFL3	Pithecellobium flexicaule
		POAN4	Porlieria angustifolia
		LEFR3	Leucophyllum frutescens
			Schaefferia cuneifolia
		TRRA2	Trixis radialis
		DITE3	Diospyros texana
		EUPR3	Euphorbia prostrata
		PHVI6	Physalis viscosa
		AMPS	Ambrosia psilostachya
			Prosopis reptans var. cinerascens
		GABR2	Gaura brachycarpa
		CYBA	Cynanchum barbigerum
			Zizphus obtusifolia
		PACO11	Parthenium confertum
		PHORA	Phoradendron sp.
		PSGN	Psilostrophe gnaphloides
		ACRI	Acacia rigidula
		SOTR2	Solanum triguetrum
		CODI	Cocculus diversifolius
		*RACO3	Ratibida columnaris
		ACOB2	Acleisanthes obtusa
			Krameria ramosissima
		EPAN	Ephedra antisyphilitica
		*EYAN	Eysenhardtia texana
		OPLE	Opuntia leptocaulis
		ZEHI	Zexmenia hispida
WT-131	Summer	ACACI	Acacia sp.
		QUERC	Quercus sp.
		POAN4	Porlieria angustifolia
		RHMI3	Rhus microphylla
		DALEA	Dalea sp.
		CERCO	Cercocarpus sp.
		NOER	Nolina erumpens
		DITE3	Diospyros texana
		VIGUI	Viguiera sp.
		JUNIP	Juniperus sp.
		VERBE	Verbena sp.
		MENOD	Menodora sp.
		MENTH	Mentha sp.
		ECHIN3	Echinocereus sp.
	Late Summer	RHVI3	Rhus virens
		DALEA	Dalea sp.
		RHUS+	Rhus sp.
		CERCO	Cercocarpus sp.
		RHTR	Rhus trilobata
		DYSSO	Dyssodia sp.
		PICE	Pinus cembroides
		EUSE6	Euphorbia serrula
		ERDI4	Erigeron divergens
		VERBE	Verbena sp.
		ARTEM	Artemisia sp.
		SETCR	Setcreasea sp.
		AGLE	Agave lechegulla
		OPEN2	Opuntia engelmannii

Appendix Table IV.14. (Continued)

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
	Winter	QUERC	Quercus sp.
		POAN4	Porlieria angustifolia
		DALEA	Dalea sp.
		RHUS+	Rhus sp.
		CERCO	Cercocarpus sp.
		RHTR	Rhus trilobata
		DYSSO	Dyssodia sp.
		DITE3	Diospyros texana
		JUNIP	Juniperus sp.
		EUSE6	Euphorbia serrula
		VERBE	Verbena sp.
		ARHU5	Argythamnia humilis
		MENOD	Menodora sp.
		*HOUST	Hedyotis sp.
		ARTEM	Artemisia sp.
		BOUTE	Bouteloua sp.
	Spring	DYSSO	Dyssodia sp.
		FRGR2	Fraxinus gregil
		FAPA	Fallugia paradoxa
		FOAN	Foresteria angustifolia
		PHORA	Phoradendron sp.
		VIGUI	Viguiera sp.
		PEHA2	Penstemon havardii
		CROTO	Croton sp.
WT-135		CAER	Calliandra eriophylla
		QUOB	Quercus oblongifolia
		CERE2	Celtis reticulata
		MIDY	Mimosa dysocarpa
		FOSP2	Fouquieria splendens
		ACGR	Acacia greggii
		ANTH2	Aniscanthus thurberi
		BOCU	Bouteloua curtipendula
WT-137	Summer	RHTR	Rhus trilobata
		RONU	Rosa nutkana
		SALIX	Salix sp.
		APCA	Apocynum cannabinum
		COAR4	Convolvulus arvense
		HELIA3	Helianthus sp.
		KOSC	Kochia scoparia
		RUMEX	Rumex sp.
		HORDE	Hordeum sp.
			Gramineae
	Fall	COST4	Cornus stolonifera
		PIPO	Pinus ponderosa
			Pseudotsuga taxifolia
		RONU	Rosa nutkana
		SALIX	Salix sp.
		COAR4	Convolvulus arvense
		KOSC	Kochia scoparia
		RUMEX	Rumex sp.
		HORDE	Hordeum sp.
			Gramineae
	Winter	ARCA13	Artemisia cana
		ARTR2	Artemisia tridentata
		CHVI8	Chrysothamnus vicidiflorus
		PIPO	Pinus ponderosa
		RONU	Rosa nutkana
		SALIX	Salix sp.
		CERE3	Centaurea repens
		MESA	Medicago sativa
		RUMEX	Rumex sp.
		YUGL	Yucca glauca
			Gramineae

Appendix Table IV.14. (Continued)

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
	Spring	ARCA13	Artemisia cana
		ARTR2	Artemisia tridentata
		CHVI8	Chysothamnus vicidiflorus
			Pseudotsuga taxifolia
		RHTR	Rhus trilobata
		RONU	Rosa nutkana
		SALIX	Salix sp.
		KOSC	Kochia scoparia
		MESA	Medicago sativa
		RUMEX	Rumex sp.

*Nomenclature or authority change since time of publication

Appendix Table IV.15. Elk, diet components with composition proportion of 5 percent or greater compiled from the scientific literature.

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 13 FA	Summer	Ref. 17 FA	Warm Season	Cool Season	Ref. 28 FA	Yearly	Ref. 86 VE	Summer	Ref. 89 FA	Spring - Summer	Winter	Ref. 90 OE	Summer	Winter	Ref. 126 RA & OE	Summer - Fall	Ref. 127 OE & RA	Spring	Summer	Ref. 132 FA	Winter	Spring	Summer	Fall	Ref. 133 OE & CP	Winter	SCS PLANT CODE
	TOTAL GRASSES																		46		77	16		24	64	45	40		63	
CAREX	Carex sp.	C_3+		32		16							71	23		43	6								8	15	7			CAREX
STIPA	Stipa sp.	C_3		10		12	5		14																		6			STIPA
AGROP2	Agropyron sp.	C_3		9					46																6					AGROP2
AGSM	Agropyron smithii	C_3					25																							AGSM
BRIN2	Bromus inermis	C_3				5	16																							BRIN2
FESTU	Festuca sp.	C_3				25	6																	7	17	12	6			FESTU
POA++	Poa sp.	C_3				14	10														7	6			7		6			POA++
JUBA	Junucus balticus															6														JUBA
DECAS	Deschampsia caespitosa	C_3														6														DECAS
POPR	Poa pratensis	C_3															25													POPR
MUMO	Muhlenbergia montana	C_4+															9													MUMO
PRPR3	Phleum pratense	C_3															5													PRPR3
AGSP	Agropyron spicatum	C_3																			5								35	AGSP
FEID	Festuca idahoensis	C_3																			55								18	FEID
FESC	Festuca scabrella	C_3																			5									FESC
MUHLE	Muhlenbergia sp.	C_4+																							8					MUHLE
	Unidentified grasses												22	13										12	13	9	5			

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 13 FA	Summer	Ref. 17 FA	Warm Season	Cool Season	Ref. 28 FA	Yearly	Ref. 86 VE	Summer	Ref. 89 FA	Spring - Summer	Winter	Ref. 90 OE	Summer	Winter	Ref. 126 RA & OE	Summer - Fall	Ref. 127 OE & RA	Spring	Summer	Ref. 132 FA	Winter	Spring	Summer	Fall	Ref. 133 OE & CP	Winter	SCS PLANT CODE
	TOTAL FORBS										100								36		23	76			6	27	3		10	
WYETH	Wyethia sp.										32																			WYETH
TRIFO	Trifolium sp.	C_3+									28																			TRIFO
GEVI2	Geranium viscosissimum										25																			GEVI2
POFR4	Potentilla fruticosa	C_4+															5													POFR4
LUPIN	Lupinus sp.	C_3+																	5											LUPIN
XETE	Xerophyllum tenax																		24											XETE
ACMI2	Achillea millefolium	C_3																				11								ACMI2
POTEN	Potentilla sp.	C_4+																				8				9				POTEN
TARAX	Taraxacum sp.	C_3+																				22								TARAX
TRRE3	Trifolium repens	C_3+																				11								TRRE3
ERIOG	Eriogonum sp.	C_4+																								7				ERIOG
	Unidentified forbs										16											7				7				

Appendix Table IV.15. (Continued)

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 13 FA	Summer	Ref. 17 FA	Warm Season	Cool Season	Ref. 28 FA	Yearly	Ref. 86 VE	Summer	Ref. 89 FA	Spring-Summer	Winter	Ref. 90 OE	Summer	Winter	Ref. 126 RA & OE	Summer-Fall	Ref. 127 OE & RA	Spring	Summer	Ref. 132 FA	Winter	Spring	Summer	Fall	Ref. 133 OE & CP	Winter	SCS PLANT CODE
	TOTAL SHRUBS												5	64					18			6		74	30	27	51		30	
CERCO	Cercocarpus sp.			20																										CERCO
PUTR2	Purshia tridentata								22																					PUTR2
CEMO2	Cercocarpus montanus						5																							CEMO2
SALIX	Salix sp.													44			9					7								SALIX
AMAL2	Amelanchier alnifolia													18																AMAL2
SAPHP	Salix planifolia															8														SAPHP
SABR	Salix brachycarpa															6														SABR
POTR5	Populus tremuloides																7													POTR5
BERE	Berberis repens																		7											BERE
ARTR2	Artemisia tridentata	C_3																											11	ARTR2
PSME	Pseudotsuga menziesii																							8					5	PSME
YUCCA	Yucca sp.	C_3																						5			5			YUCCA
ARTEM	Artemisia sp.																							48	17	5	7			ARTEM
SHEPH	Shepherdia sp.																									9				SHEPH
ATRIP	Atriplex sp.																										6			ATRIP
EUROT	Eurotia sp.																										12			EUROT
CHRYS9	Chrysothamnus sp.	C_4+																									7			CHRYS9
	Unidentified shrubs																									5	8			

\+ Provisional photosynthetic pathway assignment

Appendix Table IV.16. Elk, additional diet components with composition proportion of less than 5 percent compiled from the scientific literature.

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
E- 13		ARTR2	Artemisia tridentata
		EULA5	Eurotia lanata
		AMUT	Amelanchier utahensis
		KOCR	Koeleria cristata
		BROMU	Bromus sp.
		ORHY	Oryzopsis hymenoides
		PIED	Pinus edulis
E- 28	Annual Average	ATRIP	Atriplex sp.
		ARTEM	Artemisia sp.
		ORHY	Oryzopsis hymenoides
		CAREX	Carex sp.
		EULA5	Eurotia lanata
		BROMU	Bromus sp.
		POA++	Poa sp.
		ROSA+	Rosa sp.
		SAKA	Salsola kali
		SAVE4	Sarcobatus vermiculatus
		ELCO	Elaeagnus commutata
		*FESTU	Vulpia sp.
		SPORO	Sporobolus sp.
		LESQU	Lesquerella sp.
		CHNA2	Chrysothamnus nauseosus
		CRYPT	Cryptantha sp.
		DIST	Distichlis stricta
E- 66	Spring/Summer	JUNIP	Juniperus sp.
		BERE	Berberis repens
		QUGA	Quercus gambelii
		BOGR2	Bouteloua gracilis
		CEMO2	Cercocarpus montanus
		MUHLE	Muhlenbergia sp.
			Falsetarragon sagewort
		ARTR2	Artemisia tridentata
		AGSM	Agropyron smithii
		HODU	Holodiscus dumosus
		YUGL	Yucca glauca
		CHRYS9	Chrysothamnus sp.
			Spring parsley
		ERIGE2	Erigeron sp.
		LESQU	Lesquerella sp.
		LUPIN	Lupinus sp.
			Lanceleaf bluebells
		OPUNT	Opuntia sp.
		PIED	Pinus edulis
		RHUS+	Rhus sp.
		SHEPH	Shepherdia sp.
		SPHAE	Sphaeralcea sp.
	Fall/Winter	EULA5	Eurotia lanata
		JUNIP	Juniperus sp.
		CHRYS9	Chrysothamnus sp.
		CAREX	Carex sp.
		BOGR2	Bouteloua gracilis
		MUHLE	Muhlenbergia sp.
		BERE	Berberis repens
		GUTIE	Gutierrezia sp.
		DANTH	Danthonia sp.
		ORHY	Oryzopsis hymenoides
		SPORO	Sporobolus sp.
		ALNUS	Alnus sp.
		ATRIP	Atriplex sp.
		ERIGE2	Erigeron sp.
		LESQU	Lesquerella sp.
		LUPIN	Lupinus sp.
			Lanceleaf bluebells
		QUGA	Quercus gambelli
		SHEPH	Shepherdia sp.
		YUGL	Yucca glauca

Appendix Table IV.16. [illegible]

Appendix Table IV.16. (Continued)

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
E- 89	Spring/Summer	TRIFO	Trifolium sp.
		SALIX	Salix sp.
		BEPA	Betula papyrifera
		AMAL2	Amelanchier alnifolia
		POTR5	Populus tremuloides
	Winter	POBA2	Populus balsamifera
		COCO6	Corylus cornuta
		SHCA	Shepherdia canadensis
E- 90	Summer	GERO2	Geum rossii
		*KOBE	Kobresia myosuroides
		CACA4	Calamagrostis canadensis
		VACCI	Vaccinium sp.
		CALE4	Caltha leptosepala
	Winter	CACA4	Calamagrostis canadensis
		BRIN2	Bromus inermis
		SALIX	Salix sp.
		ERUM	Eriogonum umbellatum
		STCO4	Stipa comata
		PUTR2	Purshia tridentata
E-126		PICO	Pinus contorta
		PSME	Pseudotsuga menziesii
		SALIX	Salix sp.
		ARUV	Arctostaphylos uva-ursi
		ACMI2	Achillea millefolium
		ARLA8	Arnica latifolia
		BASA3	Balsamorhiza sagittata
		CASTI2	Castilleja sp.
			Alectoria americana
E-127	Spring	AGSP	Agropyron spicatum
		FESC	Festuca scabrella
		KOCR	Koeleria cristata
		CAREX	Carex sp.
		ACMI2	Achillea millefolium
		AGGL	Agoseris glauca
		ANPA4	Antennaria parvifolia
		ARNIC	Arnica sp.
		ARFR4	Artemisia frigida
		CEAR4	Cerastium arvense
		CIRSI	Cirsium sp.
		GEVI2	Geranium viscossissimum
		GETR	Geum triflorum
		HICY	Hieracium cynoglossoides
		LUPIN	Lupinus sp.
		POTEN	Potentilla sp.
		SEDE2	Selaginella densa
		TARAX	Taraxacum sp.
	Summer	AGSP	Agropyron spicatum
		BROMU	Bromus sp.
		FEID	Festuca idahoensis
		KOCR	Koeleria cristata
		PHLEU	Phleum sp.
		CAREX	Carex sp.
		ACMI2	Achillea millefolium
		ANPA4	Antennaria parvifolia
		ARNIC	Arnica sp.
		CEAR4	Cerastium arvense
		CIRSI	Cirsium sp.
		ERUM	Eriogonum umbellatum
		FRVI	Fragaria virginiana
		GEVI2	Geranium viscossissimum
		GETR	Geum triflorum
		HICY	Hieracium cynoglossoides
		LUPIN	Lupinus sp.
		MICRO6	Microseris sp.
			Similacina racemosa
		VACCI	Vaccinium sp.

Appendix Table IV.16. (Continued)

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
E-132	Winter	MUHLE	Muhlenbergia sp.
		CAREX	Carex sp.
		JUNIP	Juniperus sp.
		PINUS	Pinus sp.
		ATRIP	Atriplex sp.
		EUROT	Eurotia sp.
		CHRYS9	Chrysothamnus sp.
	Spring	STIPA	Stipa sp.
		ELEOC	Eleocharis sp.
		JUNCU	Juncus sp.
		POTEN	Potentilla sp.
		JUNIP	Juniperus sp.
		PINUS	Pinus sp.
		PSEUD7	Pseudotsuga sp.
		SALIX	Salix sp.
		ATRIP	Atriplex sp.
		RIBES	Ribes sp.
		CERCO	Cercocarpus sp.
		CHRYS9	Chrysothamnus sp.
	Summer	POA++	Poa sp.
		AGROP2	Agropyron sp.
		MUHLE	Muhlenbergia sp.
		BOUTE	Bouteloua sp.
		KOCHI	Kochia sp.
			Compositae
		SALIX	Salix sp.
		ATRIP	Atriplex sp.
		RIBES	Ribes sp.
		CERCO	Cercocarpus sp.
		ROSA+	Rosa sp.
		RHUS+	Rhus sp.
		CHRYS9	Chrysothamnus sp.
	Fall	MUHLE	Muhlenbergia sp.
		BOUTE	Bouteloua sp.
		POTEN	Potentilla sp.
		LUPIN	Lupinus sp.
		PINUS	Pinus sp.
		PSEUD7	Pseudotsuga sp.
		SALIX	Salix sp.
		BERBE	Berberis sp.
		CERCO	Cercocarpus sp.
E-133		AGSU	Agropyron subsecundum
		CARU	Calamagrostis rubescens
		POA++	Poa sp.
		STVI4	Stipa viridula
		ACMI2	Achillea millefolium
		ARFR4	Artemisia frigida
		BASA3	Balsamorrhiza sagittata
		ERIGE2	Erigeron sp.
		LUPIN	Lupinus sp.
		SOMI2	Solidago missouriensis
		TRDU	Tragapogon dubius
		CHVI8	Chrysothamnus vicidiflorus
		JUCO6	Juniperus communis
		PICO	Pinus contorta
		POTR5	Populus tremuloides
		ROAC	Rosa acicularis
		SALIX	Salix sp.
		SHCA	Shepherdia canadensis

*Nomenclature or authority change since time of publication

Appendix Table IV.17. Feral Horses, diet components with composition proportion of 5 percent or greater compiled from the scientific literature.

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 4 ME	Spring-Summer	Fall-Winter	Ref. 13 FA	Summer	Ref. 16 FA	Summer	Ref. 17 FA	Summer	Ref. 28 FA	Yearly	Ref. 67 FA	Spring-Summer	Fall-Winter	SCS PLANT CODE
	TOTAL GRASSES																
KOCR	Koeleria cristata	C_3		12	12		6		10								KOCR
AGROP2	Agropyron sp.	C_3		6			14		13		17		37				AGROP2
SPORO	Sporobolus sp.	C_4		23	18												SPORO
LEDU	Leptochloa dubia	C_4		8	5												LEDU
CAREX	Carex sp.	C_3					27		24				5		39	30	CAREX
STIPA	Stipa sp.	C_3					27				54		36				STIPA
BROMU	Bromus sp.	C_3					9		9		9						BROMU
STCO4	Stipa comata	C_3							21								STCO4
ORHY	Oryzopsis hymenoides	C_3							7				10				ORHY
POA++	Poa sp.	C_3							6								POA++
DANTH	Danthonia sp.	C_3									6						DANTH
FESTU	Festuca sp.	C_3													22	15	FESTU
ELIN4	Elymus innovatus	C_3													22	29	ELIN4

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 4 ME	Spring-Summer	Fall-Winter	Ref. 13 FA	Summer	Ref. 16 FA	Summer	Ref. 17 FA	Summer	Ref. 28 FA	Yearly	Ref. 67 FA	Spring-Summer	Fall-Winter	SCS PLANT CODE
	TOTAL FORBS																
SAKA	Salsola kali	C_4		20	32												SAKA

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 4 ME	Spring-Summer	Fall-Winter	Ref. 13 FA	Summer	Ref. 16 FA	Summer	Ref. 17 FA	Summer	Ref. 28 FA	Yearly	Ref. 67 FA	Spring-Summer	Fall-Winter	SCS PLANT CODE
	TOTAL SHRUBS																
PRJU	Prosopis juliflora			16	17												PRJU
ATRIP	Atriplex sp.				8												ATRIP

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 4 ME	Spring-Summer	Fall-Winter	Ref. 13 FA	Summer	Ref. 16 FA	Summer	Ref. 17 FA	Summer	Ref. 28 FA	Yearly	Ref. 67 FA	Spring-Summer	Fall-Winter	SCS PLANT CODE
	OTHER																
	Unidentifiable plants														18	27	

Appendix Table IV.18. Horses, additional diet components with composition proportion of less than 5 percent compiled from the scientific literature.

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
H- 4	Spring/Summer	ATRIP	Atriplex sp.
		BOUTE	Bouteloua sp.
		MUHLE	Muhlenbergia sp.
		SEMA5	Setaria macrostachya
	Fall/Winter	AGROP2	Agropyron sp.
		BOUTE	Bouteloua sp.
		MUHLE	Muhlenbergia sp.
		SEMA5	Setaria macrostachya
	Yearlong	ANDRO2	Andropogon sp.
		ARIST	Aristida sp.
		HILAR	Hilaria sp.
		LYCUR	Lycurus sp.
		ORYZO	Oryzopsis sp.
		PANIC	Panicum sp.
		ARTEM	Artemisia sp.
		LESQU	Lesquerella sp.
		OENOT	Oenothera sp.
		SPHAE	Sphaeralcea sp.
H- 13		ORHY	Oryzopsis hymenoides
		DANTH	Danthonia sp.
		EULA5	Eurotia lanata
		AMUT	Amelanchier utahensis
		ARTR2	Artemisia tridentata
		CECRO	Cercocarpus sp.
H- 16		EULA5	Eurotia lanata
		AMUT	Amelanchier utahesis
		FESTU	Festuca sp.
		LESQU	Lesquerella sp.
		CHRYS9	Chrysothamnus sp.
		PIED	Pinus edulis
		JUNIP	Juniperus sp.
		ARTR2	Artemisia tridentata
		CEMO2	Cercocarpus montanus
		MERTE	Mertensia sp.
		QUGA	Quercus gambelii
H- 22		FESTU	Festuca sp.
		CAREX	Carex sp.
		EULA5	Eurotia lanata
		ELYMU	Elymus sp.
		CERCO	Cercocarpus sp.
		KOCR	Koeleria cristata
		ARTR2	Artemisia tridentata
		PUTR2	Purshia tridentata
		JUNIP	Juniperus sp.
H- 28	Annual Average	EULA5	Eurotia lanata
		ATRIP	Atriplex sp.
		BROMU	Bromus sp.
		SYMPH	Symphoricarpos sp.
		POA++	Poa sp.
		CHNA2	Chrysothamnus nauseosus
		SPHAE	Sphaeralcea sp.
		ARTEM	Artemisia sp.
		SAKA	Salsola kali
		SAVE4	Sarcobatus vermiculatus
		*FESTU	Vulpia sp.
		SPORO	Sporobolus sp.
		DIST	Distichlis stricta

*Nomenclature or authority change since time of publication

Appendix Table IV.19. Burro, diet components with composition proportion of 5 percent or greater compiled from the scientific literature.

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 10 FA	Annual	March	Ref. 128 FA	Spring	Summer	Fall	Winter	Ref. 129 RA	Spring	Fall	SCS PLANT CODE
	TOTAL GRASSES								8	5		10	10	
TRIDE	Tridens sp.	C_4+		14										TRIDE
MUPO2	Muhlenbergia porteri	C_4		25	15									MUPO2
BRRU2	Bromus rubens	C_3+		7	44									BRRU2
PHCO15	Phragmites communis	C_3		8										PHCO15
AGSM	Agropyron smithii	C_3			11									AGSM
ARWR2	Aristida wrightii	C_4+		15										ARWR2

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 10 FA	Annual	March	Ref. 128 FA	Spring	Summer	Fall	Winter	Ref. 129 RA	Spring	Fall	SCS PLANT CODE
	TOTAL FORBS						59	18	9	22		64	13	
PLIN3	Plantago insularis	C_3			5		49	14		9				PLIN3
CRYPT	Cryptantha sp.	C_3+								7				CRYPT

SCS PLANT CODE	SCIENTIFIC NAME	PHOTOSYNTHETIC PATHWAY	Ref. 10 FA	Annual	March	Ref. 128 FA	Spring	Summer	Fall	Winter	Ref. 129 RA	Spring	Fall	SCS PLANT CODE
	TOTAL SHRUBS						34	76	78	69		26	77	
TAPE	Tamarix pentandra			9										TAPE
CEFL2	Cercidium floridum							28	21	15				CEFL2
PROSO	Prosopis sp.							18	9					PROSO
HYSA	Hymenoclea salsola							5	10	6				HYSA
PLSE	Pluchea sericea							17	8					PLSE
ACGR	Acacia greggii								11	6				ACGR
OPUNT	Opuntia sp.	C_4-CAM							5					OPUNT
	Ambrosia dumosa								5	14				

+ Provisional photosythetic pathway assignment

Appendix Table IV.20. Burro, additional diet components with composition proportion of less than 5 percent compiled from the scientific literature.

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
BO- 10		SPHAE	Sphaeralcea sp.
		ACCO2	Acacia constricta
		ERIOG	Eriogonum sp.
		TIOB	Tidestromia oblongifolia
		ARTEM	Artemisia sp.
		PHCA8	Phoradendron californicum
		CAREX	Carex sp.
		EPNE	Ephedra nevadensis
		HIRI	Hilaria rigida
		PESC4	Peucephyllum schottii
		LYCIU	Lycium sp.
		CRBI2	Crossosma bigelovii
BO-128	Spring	ARIST	Aristida sp.
		BRRU2	Bromus rubens
		SCBA	Schismus barbatus
		TRPU2	Tridens pulchellus
		SORGH	Sorgum sp.
		ERIOG	Eriogonum sp.
		MIBI8	Mirabilis bigelovii
		MENTZ	Mentzelia sp.
		OENOT	Oenothera sp.
		CRYPT	Cryptantha sp.
		GECA2	Geraea canescens
		CAWR	Calycoseris wrightii
		CEFL2	Cersidium floridum
		PROSO	Prosopis sp.
		ACGR	Acacia greggii
		KRGR	Krameria grayi
		LADI2	Larrea divaricata
		FOSP2	Fouquieria splendens
		OPUNT	Opuntia sp.
		HYEM	Hyptis emoryi
		LYAN	Lycium andersonii
		HYSA	Hymenoclea salsola
		ENFA	Encelia farinosa
		PLSE	Pluchea sericea
		*FRDU	Ambrosia dumosa
		BEJU	Bebbia juncea
	Summer	MUPO2	Muhlenbergia porteri
		SORGH	Sorghum sp.
		ERIOG	Eriogonum sp.
		CRYPT	Cryptantha sp.
		CAAR10	Cassia armata
		ACGR	Acacia greggii
		KRGR	Krameria grayi
		FOSP2	Fouquieria splendens
		HYEM	Hyptis emoryi
		LYAN	Lycium andersonii
		ENFA	Encella farinosa
		*FRDU	Ambrosia dumosa
	Fall	ARIST	Aristida sp.
		MUPO2	Muhlenbergia porteri
		BRRU2	Bromus rubens
		TRPU2	Tridens pulchellus
		SORGH2	Sorghum sp.
		ERIOG	Eriogonum sp.
		OENOT	Oenothera sp.
		PECTO	Pectocarya sp.
		CRYPT	Cryptantha sp.
		MIBI6	Mimulus bigelovii
		PLIN3	Plantago insularis
		DASC	Dalea schottii
		KRGR	Krameria grayi
		LADI2	Larrea divaricata
		SPAM2	Sphaeralcea ambigua
		FOSP2	Fouqueria splendens
		LYAN	Lyciun andersonii
		BEJU	Bebbia juncea
		PESC4	Peucephyllum schottii

Appendix Table IV.20. (Continued)

REFERENCE	TREATMENT/SEASON	SCS PLANT CODE	SCIENTIFIC NAME
	Winter	ARIST	Aristida sp.
		MUPO2	Muhlenbergia porterl
		SCBA	Schismus barbatus
		SORGH2	Sorghum sp.
		ERIOG	Eriogonum sp.
		OENOT	Oenothera sp.
			Langloisia setosissima
		PECTO	Pectocarya sp.
		MIBI6	Mimulus bigelovii
		GECA2	Geraea canescens
		CAWR	Calycoseris wrightii
		CAAR10	Cassia armata
		PROSO	Prosopsis sp.
		DASC	Dalea schottii
		KRGR	Krameria grayi
		LADI2	Larrea divaricata
		SPAM2	Sphaeralcea ambigua
		FOSP2	Fouqueria splendens
		OPUNT	Opuntia sp.
		HYEM	Hyptis emoryi
		LYAN	Lucium andersonii
		ENFA	Encelia farinosa
		PLSE	Pluchea sericea
		BEJU	Bebbia juncea
		PESC4	Peucephyllum schottii

*Nomenclature or authority change since time of publication

FOOTNOTES TO APPENDIX IV

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APPENDIX V

Optimization Algorithms
Table of Standard Normal Deviates Fractile Values (K Values)
Implemented Computer Codes
- Subroutine GCOMP: Model 5 Series
- Subroutine GCOMP: Model 6 Series
- FORTRAN Program RHS5: Model 5 Series
- FORTRAN Program RHS6: Model 6 Series

Gradient of Model 2B

Optimization Algorithms

This section consider some of the characteristics of a few of the available computational algorithms.

A great variety of computation algorithms have been developed by the scientific community for solving optimization problems. Numerous books are available on the subject. Therefore, the purpose of the present section is only to briefly review some linear and nonlinear programming algorithms which we have tested and found useful. It should be noted also that most computer manufacturing companies have available, at costs, computational algorithm packages for linear programming problems. These allow problems of large dimensionality and are quite efficient in their computing characteristics.

Program LINPRO uses the revised simplex method with an explicit inverse in solving linear programming problems. It will solve either minimization or maximization problems. One does not need to add slack, surplus, or artificial variables in setting up the problem. The program does this for you. Constraints must be read in in the following order: (i) all less than or equal to constraints first; (ii) all greater than or equal to constraints; (iii) and all equality constraints. The program allows the user to solve several problems in a single run. The output of the program shows the user the coefficients that were read in for the objective function and the coefficients that were read in for the A_{ij} matrices as well as the right-hand side B_i. The output gives the slack and the surplus variables. The optimal value of the decision variables and the optimal value of the objective function are also provided along with a complete sensitivity analysis that includes the dual variables and a full right-hand side and cost coefficient range. This program uses a subroutine titled SIMPLX which is a commercial explicit inverse revised simplex code developed by the Rand Corporation.

A quadratic programming program is one in which the objective function is quadratic in nature whereas the constraints are linear. Programs LEMKE and QUAD are quadratic programming algorithms. In LEMKE a complementary pivoting algorithm solves the linear complementary problem. After introducing the artificial variable Z_0, the algorithm moves from one almost complementary basic feasible solution to another until either a complementary basic feasible solution is obtained or a direction indicating unboundness of the region is found (Lemke 1968).

Program QUAD uses the procedure credited to Wolfe (1959) for solving quadratic programming problems. The method uses the simplex method to find a Kuhn-Tucker point by minimizing the sum of artifical variables. The algorithm makes use of a restricted basis entry rule that maintains complementary slackness with each pivot.

Program GRG and GRG2 solve non-linear objective functions subject to linear or non-linear constraints, either inequalities or equalities (Abadie 1970). Upper and lower bounds on the variables are optional and if present are not treated as additional constraint functions but are handled separately. The program uses the Generalized Reduced Gradient method. The users provide subroutines to evaluate the objective function for any given solution vector x. The program calculates first partial derivatives of each function with respect to each variable. These are automatically computed by finite

difference approximation, though there are several methods available in GRG for the user to pick from, less the user provides a subroutine which evaluates them analytically. All non-linear algorithms are sensitive to the initial starting point as a feasible starting point is needed in order to solve for an optimal feasible point. If the user does not supply a feasible starting point the algorithm has a few methods to select from which will attempt to do so. There is no foolproof method which solves the phase one problem for non-linear functions; the program may get stuck attempting to find an initial feasible point. The program is written in FORTRAN and has about 4500 statements including comments. The program requires a user supplied subroutine which, given the current X vector, computes the vector of the function values one of which is the objective function and the others are the constraints. Optionally, the user may supply a subroutine which gives output reports. A detailed user guide is available for this routine.

These are but a few of the algorithms available for linear and nonlinear programming models. The overall strategy in selecting an algorithm is to get one that meets the problem requirements, has good documentation, and with which others have had experience on a local installation. The main computational characteristics of concern are whether the objective function is linear, quadratic, or nonlinear and whether the constraints are linear or nonlinear and whether they are inequalities, equalities or both. The most general of the above routines appears to be GRG. However, if a simpler problem is formulated (e.g., a linear programming optimization problem) then perhaps the most general routine may not be as efficient or as easy to use as other routines. Many of these routines are available as subroutines and can then be called from a user-defined main program which may do many other calculations. Most of these algorithms are sufficiently complex, however, in that they are stand-alone main programs and may incorporate user-defined subroutines.

Table of Standard Normal Deviates Fractile Values (K Values)

The standard normal deviates used in the stochastic Model 5 and 6 series is given below. All of the values where used in the Model 5 series and all but the 99% fractile were used in the Model 6 series. The fractiles represent two-tailed values.

STD. DEV.	FRACTILE
0.0	0
0.25	.20
0.52	.40
0.84	.60
1.28	.80
1.645	.90
1.96	.95
3.9	.99

Implemented Computer Codes

The user supplied computer code for subroutine GCOMP, for the single-season models, Model 5 series, and multiple-season models, Model 6 series; and the Right-hand-side generating program for the Model 5 series, RHS5, and the Model 6 series, RHS6, is given in the following sections.

difference approximation, though there are several options available to the user to pick from, less any that provides a non-linear [illegible] them analytically. All non-linear objectives are available for [illegible] starting point as a feasible starting point other than [illegible] a general feasible point. If the user does not supply a feasible starting point, the algorithm has a few methods to select from which [illegible] to use. There is no "optimal" method which solves the objective [illegible] functions; the program may not [illegible] [illegible] [illegible] points. The algorithm is written in FORTRAN and [illegible] lines including comments. The solution requires a user supplied [illegible] given the current X vector, computes the vector of the function values, which is the objective function and the vector of the constraints. Optionally, the user may supply a subroutine which gives output [illegible]. A detailed user guide is available for this algorithm.

There are but a few of the algorithms available for solving mathematical programming models. The general strategy of selecting an algorithm is one that makes the problem requirements fit those of [illegible] which others have had experience and which [illegible] computational. Characteristics of concern are whether the objective function is linear, quadratic, or nonlinear and whether the constraints are linear or nonlinear and whether they are inequalities, equalities or [illegible]. The general of the model requires the problem to be solved [illegible] problem is unconstrained then, a linear programming routine [illegible] perhaps the most general routine may not be as efficient [illegible] other routines. Many of these routines are available in [illegible] than be called from a user-written main program which [illegible] calculations. Many of these algorithms are sufficiently [illegible] that they are stand-alone main programs and [illegible] subroutines.

<u>Table of Standard Normal Deviates Percentile Values of Variates</u>

The standard normal deviates used in the [illegible] is given below. All of the values [illegible] but the [illegible] were used in the [illegible] tabulated values.

Percentile	Std. dev.
.5	0.0
.60	0.25
.70	0.52
.80	0.84
.90	1.28
.95	1.645
.975	1.96
.99	2.33

<u>Implemented Computer Codes</u>

The user supplied [illegible] code for [illegible], the simulation [illegible] Model 3 [illegible], and [illegible] Model 4 [illegible] and the [illegible] program for the Model 5 [illegible] and the Model 6 [illegible] is given in the following [illegible].

Subroutine GCOMP: Model 5 Series

The code of FORTRAN subroutine GCOMP, as implemented in Model 5A1, follows along with some sample output of the results. The only differences in the other Model 5 series routines (5A2, 5B, and 5C) is in the objective function.

```
      SUBROUTINE GCOMP (G,X)

C.....GRG2 SUBROUTINE FOR MODEL 5 SERIES
C        WRITTEN BY PAUL KORTOPATES     -- REV. 1-28-81

      REAL G(1), X(1)

      REAL H, T, C(4,2), D(5,4), REQUIR(4), PENALG(5,4), PENALH(4)
      REAL FRACTL, VARC(4), STDDEV(8)
      REAL S(5), GR(5), U(5), L(5), AUE(4)
      INTEGER RUN

      COMMON /INITBK/ INIT

C.....CONSTANTS
      DATA H,T / 10000., 365./
      DATA AUE / .609, .569, .132, .080/

C.....PLANT DATA
      DATA U / .45, .46, .45, .46, .37/
      DATA S / 50., 3*5., 15./
      DATA GR / 600., 240., 70., 55., 100./
      DATA L / .32, .40, .42, .46, .33/

C.....ANIMAL DATA
      DATA ((C(I,J),I=1,4),J=1,2)/
     1 6.05, 4.37, 1.33, .757,    2*17., 2*27./

C.....PLANT-ANIMAL DATA
      DATA ((D(I,J),I=1,5),J=1,4)/
     1 .66, .27, .01, .04, .02,
     2 .39, .31, .07, .11, .12,
     3 .23, .27, .04, .15, .31,
     4 .19, .39, .04, .35, .03/

C.....STD. DEV. FRACTILES
      DATA  RUN/0/
C.....STD. DEV. FRACTILE CORRESPOND TO 0,20,40,60,80,90,95,99.% LEVEL OF CONFI.
      DATA STDDEV/ 0.0, .25, .52, .84, 1.28, 1.645, 1.96, 3.9/

      IF (INIT.EQ.0) GOTO 90
C.....COMPUTE VARIANCES IF FIRST CALL
      RUN = RUN + 1
      FRACTL = STDDEV(RUN)

      IF (RUN.GT.1) GOTO 90
      DO 30 J=1,4
        DO 30 I=1,5
          VARC(J) = (C(J,1) * C(J,2) / 100.)**2
 30   CONTINUE
```

[illegible] Model 1 [illegible]

The code of [illegible] follows along with some sample output of the results. The only differences [illegible] the other Model 1 versions [illegible] function.

[illegible]

```
C.....COMPUTE CONSTRAINTS
C
C.....COMPUTE HERBIVORE REQUIREMENTS AND PENALTY FUNCTIONS
 90   DO 100 J = 1,4
        REQUIR(J) = X(J) * C(J,1) * T
        PENALM(J) = FRACTL * SQRT((T * X(J))**2 * VARC(J))

        DO 100 I = 1,5
          PENALG(I,J) = FRACTL * SQRT((T * X(J) * D(I,J))**2 * VARC(J))
 100  CONTINUE

C.....COMPUTE SITE MAINTENANCE CONSTRAINT
      G(1) = 0.0
      DO 110 J = 1,4
        G(1) = G(1) + REQUIR(J) + PENALM(J)
 110  CONTINUE

C.....COMPUTE OVER-GRAZING CONSTRAINTS
      DO 120 I = 1,5
        G(I+1) = 0.0
        DO 120 J = 1,4
          G(I+1) = G(I+1) + REQUIR(J) * D(I,J) + PENALG(I,J)
 120  CONTINUE

C.....COMPUTE AVAILABLE OUTPUT FUNCTIONS: % BY CLASS AND TOT. IN KG
      G(12) = 0.
      DO 130 I = 1,5
        G(6+I) = H * U(I) * (S(I) + GR(I)) * (1. - L(I))
        G(12) = G(12) + G(6+I)
 130  CONTINUE

      DO 140 I = 1,5
 140    G(6+I) = G(6+I) / G(12) * 100.

C.....COMPUTE DIET COMPOSTION % OF HERBIV. COMBIN.
      G(18) = 0.
      DO 150 J =1,4
 150    G(18) = G(18) + REQUIR(J)

      DO 160 I = 1,5
        G(12+I) = 0.
        DO 170 J = 1,4
 170      G(12+I) = G(12+I) + REQUIR(J) * D(I,J)
        G(12+I) = G(12+I) / G(18) * 100.
 160  CONTINUE

C.....COMPUTE GRAZING OUTPUT FUNCTIONS: % BY SPECIES & TOTAL GRAZED IN KG
      DO 180 J = 1,4
 180    G(18+J) = REQUIR(J) / G(18) * 100.

C.....COMPUTE TOTAL NUMBER OF A.U.E.'S
      G(23) = 0.
      DO 190 J = 1,4
 190    G(23) = G(23) + X(J) * AUE(J)

C.....COMPUTE OBJECTIVE FUNCTION VALUE
      G(24) = G(18)

      RETURN
      END
```

FINAL RESULTS

LINEAR, SINGLE-SEASON, NON-WEIGHTED, DETERMINISTIC MODEL -- MODEL 5A1

SECTION 1 -- CONSTRAINTS

NO.	NAME	INITIAL VALUE	FINAL VALUE	STATUS	DISTANCE FROM NEAREST BOUND	LAGRANGE MULTIPLIER
1	SITE MIN	.45551E+04	.25044E+07	FREE	.491E+07:U	
2	C-G WSG	.22437E+04	.14619E+07	FREE	.527E+06:U	
3	C-G CSG	.13295E+04	.67620E+06	UPPERBND	.270E-04:U	.37037E+01
4	C-G WSF	.16421E+03	.38370E+05	FREE	.157E+06:L	
5	C-G CSF	.43331E+03	.14904E+06	UPPERBND	.205E-04:U	.16632E-08
6	C-G SHRB	.39435E+03	.17891E+06	FREE	.106E+06:U	
7	WSG %	.60363E+02	.60363E+02	IGNORED	.100E+32	
8	CSG %	.20522E+02	.20522E+02	IGNORED	.100E+32	
9	WSF %	.59407E+01	.59407E+01	IGNORED	.100E+32	
10	CSF %	.45231E+01	.45231E+01	IGNORED	.100E+32	
11	SHRB %	.86519E+01	.86519E+01	IGNORED	.100E+32	
12	T. AVAIL	.32951E+07	.32951E+07	IGNORED	.100E+32	
13	DIET WSG	.49149E+02	.58373E+02	IGNORED	.100E+32	
14	DIET CSG	.29124E+02	.27000E+02	IGNORED	.100E+32	
15	DIET WSF	.35970E+01	.15321E+01	IGNORED	.100E+32	
16	DIET CSF	.94319E+01	.59510E+01	IGNORED	.100E+32	
17	DIET SHR	.86384E+01	.71436E+01	IGNORED	.100E+32	
18	T GRAZED	.45551E+04	.25044E+07	IGNORED	.100E+32	
19	CAT GRZ%	.48373E+02	.82263E+02	IGNORED	.100E+32	
20	BIS GRZ%	.34940E+02	-.63689E-05	IGNORED	.100E+32	
21	SHP GRZ%	.10634E+02	.17737E+02	IGNORED	.100E+32	
22	ANT GRZ%	.60526E+01	.10034E-13	IGNORED	.100E+32	
23	TOT. AUE	.13900E+01	.68897E+03	IGNORED	.100E+32	
24	OBJ FUNC	.45551E+04	.25044E+07	OBJ		

SECTION 2 -- VARIABLES

NO.	NAME	INITIAL VALUE	FINAL VALUE	STATUS	DISTANCE FROM NEAREST BOUND	REDUCED GRADIENT
1	CATTLE	.10000E+01	.93298E+03	BASIC	.933E+03:L	
2	BISON	.10000E+01	-.10000E-03	NONBASIC	LOWERBND	-.23630E+03
3	SHEEP	.10000E+01	.91503E+03	BASIC	.915E+03:L	
4	PRONGHN	.10000E+01	.90949E-12	NONBASIC	LOWERBND	-.12290E+03

Subroutine GCOMP: Model 6 Series

The code of FORTRAN subroutine GCOMP and Real Function 5, as implemented in Model 6A1, follows along with some sample output of the results. The only differences in the other Model 6 series routines (6A2, 6B, and 6C) is in the objective function.

```
      SUBROUTINE GCOMP (G,Y)

C.....             WRITTEN BY PAUL KORTOPATES          REV. 2-81
C..... PROGRAM THAT CALCULATES THE OBJECTIVE FUNCTION AND CONSTRAINTS
C.....FOR THE MODEL 6 SERIES, USED TO INTERFACE WITH THE GRG2 OPTIMIZATION
C.....CODE FOR NON-LINEAR PROGRAMMING PROBLEMS.

      REAL G(1), Y(1), X(4,4)

      REAL T, H, C, GR, D, L, VARC(4,4), AUE(4,4), AVAIL, GRAZED
      REAL U(5,4), PENALM(4), PENALG(5,4), FRACTL
      REAL REQUIR(4,4), REQUIRM(4), REQUIRG(5,4), TEMP, TEMP2
      REAL STDDEV(8)

      INTEGER RUN, I, II, J, K, KK, LL, M

      COMMON /INITBK/ INIT
      COMMON /SFUNC/GR(5,4),L(5,4),T(4),H,C(4,4),D(5,4,4)

C.....DATA CONSTANTS
      DATA H /10000.0/, T/ 60.,90.,75.,140./, RUN/0/

      DATA ((AUE(J,K),J=1,4),K=1,4)/
     1 .396, .363, .084, .057,
     2 .513, .476, .110, .070,
     3 .632, .593, .136, .070,
     4 .749, .705, .165, .099/

C.....STD. DEV. FRACTILES CORRESPOND TO 0,20,40,60,80,90,95 & 99% LEVELS
      DATA STDDEV / 0.0, .25, .52, .84, 1.28, 1.645, 1.96, 3.9/

C.....PLANT DATA
      DATA ((GR(I,K),I=1,5),K=1,4)/
     1 240., 200., 20., 45., 30.,
     2 360., 20., 50., 5., 60.,
     3 0., 20., 0., 5., 10.,
     4 5*0./

      DATA ((U(I,K),I=1,5),K=1,4)/
     1 .3, .1, .3, 2*.1,
     2 .1, .3, .1, .3, .1,
     3 4*.5, .3,
     4 5*.7/

      DATA ((L(I,K),I=1,5),K=1,4)/
     1 .1, .05, 2*.1, .05,
     2 .05, .1, .05, .2, .05,
     3 .1, .5, 2*.6, .2,
     4 5*.7/
```

```
C.....ANIMAL DATA
      DATA ((C(J,K),J=1,4),K=1,4)/
     1 3.96, 2.81, .84, .55,
     2 6.15, 4.41, 1.32, .81,
     3 6.31, 4.57, 1.36, .67,
     4 6.73, 4.9, 1.49, .85/

      DATA ((VARC(J,K),J=1,4),K=1,4)/
     1 2*12., 2*30.,
     2 2*18., 2*24.,
     3 2*18., 2*24.,
     3 2*21., 2*30./
C.....PLANT-ANIMAL DATA
      DATA (((D(I,J,K),J=1,4),I=1,5),K=1,4)/
     1.6,.34,.25,.03,  .27,.18,.14,.18,  .04,.17,.12,.04,
     2.09,.28,.37,.75,  0.,.03,.12,0.,
     3.63,.36,.21,.14,  .27,.26,.22,.26,  .02,.13,.08,.04,
     4.07,.18,.27,.55,  .01,.07,.22,.01,
     5.67,.46,.33,.26,  .27,.3,.26,.44,   .01,.03,.01,.04,
     6.03,2*.06,.22,    .02,.15,.34,.04,
     7.69,.38,.19,.26,  .27,.40,.36,.53,  0.,.01,0.,.04,
     8.01,.02,.02,.12,  .03,.19,.43,.05/

C.....STD. DEV. FRACTILES
      DATA FRACTL/ 0.0/

C.....IF THE FIRST CALL: CALCULATE VARIANCES
      IF (INIT .EQ. 0) GOTO 90
      RUN = RUN + 1

C.....CALCULATE VARIANCES
      DO 300 K = 1,4
        DO 300 J = 1,4
 300      VARC(J,K) = (C(J,K) * VARC(J,K) / 100.)**2

      FRACTL = STDDEV(RUN)
      PRINT  1, RUN, FRACTL
 1    FORMAT (1H0,10X,*RUN #*,I3,*STD. NORMAL DEV. FOR FRAC. IS*,F6.3)

C.....COMPUTE CONSTRAINTS
C
C.....EQUIVALENCE X(J,K)'S TO Y'S
 90   CONTINUE
      KK = 0
      DO 400 K = 1,4
        DO 400 J = 1,4
          KK = KK + 1
 400    X(J,K) = Y(KK)

C.....COMPUTE HERBIVORE REQUIREMENTS AND LEFT HAND SIDE OF AVAILABLE
      DO 500 K = 1,4
        REQUIRM(K) = 0.0

        DO 501 J = 1,4
 501      REQUIR(J,K) = T(K) * X(J,K) * C(J,K)
```

```
         DO 500 I = 1,5
           REQUIRG(I,K) = 0.

           DO 500 M = 1,K
             TEMP2 = TEMP = 0.

             DO 502 J = 1,4
502            TEMP2 = TEMP = TEMP + REQUIR(J,M) * D(I,J,M)

             II = M + 1
             IF (II.GT.K) GOTO 504
             DO 503 LL = II,K
503            TEMP= TEMP * (1.0 - L(I,LL))

             TEMP2 = TEMP * U(I,K)
504          REQUIRM(K) = REQUIRM(K) + TEMP
500          REQUIRG(I,K) = REQUIRG(I,K) + TEMP2
C.....COMPUTE PENALTY FUNCTIONS OF CONSTRAINTS
        DO 600 K = 1,4
          PENALM(K) = 0.
          DO 600 I = 1,5
            PENALG(I,K) = 0.

            KK = K - 1
            DO 601 M = 1,KK
              DO 601 J = 1,4
                TEMP = T(M) * X(J,M) * D(I,J,M)

                II = M + 1
                DO 602 LL = II,K
602               TEMP = TEMP * (1. - L(I,LL))

                PENALG(I,K) = PENALG(I,K) +
     1                 SQRT((TEMP*U(I,K))**2 * VARC(J,M))

                PENALM(K) = PENALM(K) + SQRT(TEMP**2 * VARC(J,M))
601         CONTINUE

            TEMP = 0.
            DO 603 J = 1,4
603           TEMP = TEMP + SQRT((T(K)*X(J,K)*D(I,J,K))**2 * VARC(J,K))

            PENALG(I,K) = PENALG(I,K) + TEMP
            PENALM(K)   = PENALM(K)   + TEMP
600     CONTINUE


C......COMPUTE CONSTRAINTS
C
C......COMPUTE SITE MAINTENANCE CONSTRAINTS  (4 CONSTRAINTS)
        DO 700 K = 1,4
700       G(K) = REQUIRM(K) + FRACTL * PENALM(K)

C.....COMPUTE OVERGRAZING CONSTRAINTS  (20 CONSTRAINTS)
        KK = 4
        DO 800 K = 1,4
          DO 800 I = 1,5
            KK = KK + 1
800         G(KK) = REQUIRG(I,K) + FRACTL * PENALG(I,K)
```

```
C.....COMPUTE NO SEASONAL INCREASE CONSTRAINTS  (12 CONSTRAINTS)
      DO 1100 K = 2,4
        DO 1100 J = 1,4
          KK = KK + 1
 1100     G(KK) = X(J,K) - X(J,K-1)

C.....COMPUTE STANDING CROP FOR K=2 TO 4 (FOR OUTPUT ONLY)
      DO 900 K = 2,4
         DO 900 I = 1,5
          KK = KK + 1
 900      G(KK) = S(I,K,X)

C.....COMPUTE AVAILABLE OUTPUT FUNCTIONS@D % BY SPECIES AND SEASONAL TOTAL &
C.....COMPUTE DIET COMPOSTION % OF THE ENTIRE HERB. COMBIN. BY SEASON
      II = 0
      DO 960 K = 1,4
        II = II + 1
        G(51+K*6) = 0.
        G(75+K*6) = 0.

        DO 980 J = 1,4
 980      G(75+K*6) = G(75+K*6) + REQUIR(J,K)

        DO 970 I =1,5
          II = II + 1
          G(50+II) = H * U(I,K) * (S(I,K,X) + GR(I,K)) * (1. - L(I,K))
          G(51+K*6) = G(51+K*6) + G(50+II)

          G(74+II) = 0.
          DO 990 J = 1,4
 990        G(74+II) = G(74+II) + REQUIR(J,K) * D(I,J,K)
 970    CONTINUE

        II = II - 5
        DO 960 I = 1,5
          II = II + 1
          IF (G(51+K*6).EQ.0.) GOTO 962
          G(50+II) = G(50+II) / G(51+K*6) * 100.
          GOTO 964
 962      G(50+II) = 0.
 964      IF (G(75+K*6).EQ.0.) GOTO 966
          G(74+II) = G(74+II) / G(75+K*6) * 100.
          GOTO 960
 966      G(74+II) = 0.
 960  CONTINUE

C.....COMPUTE GRAZING OUTPUT FUNCTIONS@D HERB. % OF TOTAL GRAZED
      II = 0
      DO 1000 K = 1,4
        DO 1000 J = 1,4
          II = II + 1
          IF (G(75+K*6).EQ.0.) GOTO 1002
          G(99+II) = REQUIR(J,K) / G(75+K*6) * 100.
          GOTO 1000
 1002     G(99+II) = 0.
 1000 CONTINUE
```

```
C.....COMPUTE TOTAL NUMBER OF A.U.E.'S BY SEASON AND TOTAL
      G(120) = 0.
      DO 1010 K = 1,4
        G(115+K) = 0.
        DO 1015 J = 1,4
 1015     G(115+K) = G(115+K) + X(J,K) * AUE(J,K)
        G(120)   = G(120) + G(115+K) * T(K) / 365.
 1010 CONTINUE

C.....COMPUTE OBJECTIVE FUNCTION
      G(121) = 0.
      DO 1020 I = 1,5
        DO 1020 K = 1,4
          AVAIL = H * U(I,K) * (S(I,K,X) ) * (1. - L(I,K))

          GRAZED = 0.
          DO 1030 J = 1,4
            GRAZED = GRAZED + REQUIR(J,K) * D(I,J,K)
 1030     CONTINUE

          G(121) = G(121) + ( - GRAZED )
 1020 CONTINUE
      RETURN
      END
```

```
      REAL FUNCTION S (I,K,X)

C.....                  WRITTEN BY PAUL KORTOPATES            REV. 1-81
C..... FUNCTION THAT IS USED TO RETURN THE VALUE OF THE STANDING CROP (S)
C.....GIVEN AN ARRAY OF DECISION VARIABLES AND THE DATA IN COMMON BLOCK SFUNC.

      REAL T, H, GX, REQUIR, X(4,4), L, D, C, GR
      INTEGER I, J, K, KK, M, LL
      DIMENSION SS(5)

      COMMON /SFUNC/GR(5,4),L(5,4),T(4),H,C(4,4),D(5,4,4)

      DATA SS/ 50., 5., 5., 5., 15./
      GOTO (10,20,20,20) K

 10   S = SS(I)
      RETURN

 20   S = SS(I)
      KK = K - 1
      DO 100 LL = 1,KK
        S = S * (1.0 - L(I,LL))
 100  CONTINUE

      DO 120 M = 1,KK
        GX = GR(I,M)
        DO 110 LL = M,KK
 110      GX = GX * (1.0 - L(I,LL))
        S = S + GX
 120  CONTINUE

      DO 150 M = 1,KK
        REQUIR = 0.

       DO 130 J = 1,4
 130     REQUIR = REQUIR + X(J,M) * C(J,M) * D(I,J,M)
       REQUIR = REQUIR * T(M) / H
       J = M + 1
       IF (J.GT.KK) GOTO 150
       DO 140 LL = J,KK
 140     REQUIR = REQUIR * (1.0 - L(I,LL))
 150   S = S - REQUIR
      RETURN
      END
```

FINAL RESULTS

LINEAR, MULTIPLE-SEASON, NON-WEIGHTED, DETERMINISIC MODEL -- MODEL 6A1

SECTION 1 -- CONSTRAINTS

NO.	NAME		INITIAL VALUE	FINAL VALUE	STATUS	DISTANCE FROM NEAREST BOUND	LAGRANGE MULTIPLIER
1	S-M	1	.49960E+03	.40673E+06	FREE	.525E+07:U	
2	S-M	2	.15850E+04	.13227E+07	FREE	.857E+07:U	
3	S-M	3	.20348E+04	.17808E+07	FREE	.591E+07:U	
4	S-M	4	.25662E+04	.10585E+07	FREE	.125E+07:U	
5	C-G	1,1	.21347E+03	.23354E+06	FREE	.549E+06:U	
6	C-G	2,1	.10750E+03	.10592E+06	FREE	.888E+05:U	
7	C-G	3,1	.45534E+02	.18668E+05	FREE	.488E+05:U	
8	C-G	4,1	.11199E+03	.45000E+05	UPPERBND	.466E-09:U	-.93351E+01
9	C-G	5,1	.11106E+02	.35975E+04	FREE	.392E+05:U	
10	C-G	1,2	.54702E+03	.58935E+06	UPPERBND	.373E-08:U	-.24425E+01
11	C-G	2,2	.32675E+03	.28111E+06	FREE	.295E+06:U	
12	C-G	3,2	.79413E+02	.24780E+05	FREE	.435E+05:U	
13	C-G	4,2	.20324E+03	.91316E+05	FREE	.237E+05:U	
14	C-G	5,2	.61238E+02	.24655E+05	FREE	.729E+05:U	
15	C-G	1,3	.84376E+03	.37813E+06	FREE	.178E+07:U	
16	C-G	2,3	.37785E+03	.30535E+06	FREE	.228E+06:U	
17	C-G	3,3	.41714E+02	.16299E+05	FREE	.121E+06:U	
18	C-G	4,3	.10633E+03	.49456E+05	FREE	.405E+05:U	
19	C-G	5,3	.11454E+03	.42295E+05	FREE	.216E+06:U	
20	C-G	1,4	.12288E+04	.62079E+06	FREE	.494E+06:U	
21	C-G	2,4	.76702E+03	.22394E+06	UPPERBND	.931E-09:U	-.37037E+01
22	C-G	3,4	.25350E+02	.51423E+04	FREE	.527E+05:U	
23	C-G	4,4	.75345E+02	.20522E+05	FREE	.173E+05:U	
24	C-G	5,4	.28663E+03	.27873E+05	FREE	.153E+06:U	
25	S I	1,2	0.	0.	UPPERBND	0. :U	-.17555E+02
26	S I	2,2	0.	0.	UPPERBND	0. :U	-.29602E+03
27	S I	3,2	0.	0.	UPPERBND	0. :U	-.12908E+03
28	S I	4,2	0.	0.	UPPERBND	0. :U	-.73656E+02
29	S I	1,3	0.	0.	UPPERBND	0. :U	-.37387E+03
30	S I	2,3	0.	0.	UPPERBND	0. :U	-.28823E+03
31	S I	3,3	0.	0.	UPPERBND	0. :U	-.81373E+02
32	S I	4,3	0.	0.	UPPERBND	0. :U	-.33053E+02
33	S I	1,4	0.	-.10292E+04	FREE	.103E+04:U	
34	S I	2,4	0.	.10000E-03	UPPERBND	-.100E-03:U	-.25457E+02
35	S I	3,4	0.	-.59434E+03	FREE	.595E+03:U	
36	S I	4,4	0.	.44116E-14	UPPERBND	-.441E-14:U	0.
37	S	1,2	.26098E+03	.23765E+03	IGNORED	.100E+32	
38	S	2,2	.19474E+03	.18416E+03	IGNORED	.100E+32	
39	S	3,2	.22495E+02	.20633E+02	IGNORED	.100E+32	

FINAL RESULTS

LINEAR, MULTIPLE-SEASON, NON-WEIGHTED, DETERMINISIC MODEL -- MODEL 6A1

SECTION 1 -- CONSTRAINTS

NO.	NAME	INITIAL VALUE	FINAL VALUE	STATUS	DISTANCE FROM NEAREST BOUND	LAGRANGE MULTIPLIER
40	S 4,2	.44389E+02	.40500E+02	IGNORED	.100E+32	
41	S 5,2	.42749E+02	.42390E+02	IGNORED	.100E+32	
42	S 1,3	.58988E+03	.51099E+03	IGNORED	.100E+32	
43	S 2,3	.19324E+03	.15849E+03	IGNORED	.100E+32	
44	S 3,3	.68863E+02	.64781E+02	IGNORED	.100E+32	
45	S 4,3	.39973E+02	.28348E+02	IGNORED	.100E+32	
46	S 5,3	.97605E+02	.94838E+02	IGNORED	.100E+32	
47	S 1,4	.53084E+03	.40761E+03	IGNORED	.100E+32	
48	S 2,4	.10659E+03	.67407E+02	IGNORED	.100E+32	
49	S 3,4	.27543E+02	.25101E+02	IGNORED	.100E+32	
50	S 4,4	.17984E+02	.10724E+02	IGNORED	.100E+32	
51	S 5,4	.86075E+02	.80307E+02	IGNORED	.100E+32	
52	WSG 1 %	.69109E+02	.69109E+02	IGNORED	.100E+32	
53	CSG 1 %	.17189E+02	.17189E+02	IGNORED	.100E+32	
54	WSF 1 %	.59576E+01	.59576E+01	IGNORED	.100E+32	
55	CSF 1 %	.39718E+01	.39718E+01	IGNORED	.100E+32	
56	SHRB 1 %	.37732E+01	.37732E+01	IGNORED	.100E+32	
57	T AVAIL1	.11330E+07	.11330E+07	IGNORED	.100E+32	
58	WSG 2 %	.40512E+02	.40771E+02	IGNORED	.100E+32	
59	CSG 2 %	.39816E+02	.39584E+02	IGNORED	.100E+32	
60	WSF 2 %	.47295E+01	.48136E+01	IGNORED	.100E+32	
61	CSF 2 %	.82389E+01	.78417E+01	IGNORED	.100E+32	
62	SHRB 2 %	.67032E+01	.69850E+01	IGNORED	.100E+32	
63	T AVAIL2	.14562E+07	.13926E+07	IGNORED	.100E+32	
64	WSG 3 %	.72260E+02	.72003E+02	IGNORED	.100E+32	
65	CSG 3 %	.14512E+02	.13973E+02	IGNORED	.100E+32	
66	WSF 3 %	.37492E+01	.40570E+01	IGNORED	.100E+32	
67	CSF 3 %	.24485E+01	.20885E+01	IGNORED	.100E+32	
68	SHRB 3 %	.70302E+01	.78793E+01	IGNORED	.100E+32	
69	T AVAIL3	.36735E+07	.31935E+07	IGNORED	.100E+32	
70	WSG 4 %	.69027E+02	.68952E+02	IGNORED	.100E+32	
71	CSG 4 %	.13860E+02	.11403E+02	IGNORED	.100E+32	
72	WSF 4 %	.35816E+01	.42462E+01	IGNORED	.100E+32	
73	CSF 4 %	.23385E+01	.18141E+01	IGNORED	.100E+32	
74	SHRB 4 %	.11193E+02	.13585E+02	IGNORED	.100E+32	
75	T AVAIL4	.16150E+07	.12414E+07	IGNORED	.100E+32	
76	DIETWSG1	.43602E+02	.57420E+02	IGNORED	.100E+32	
77	DIETCSG1	.21956E+02	.25042E+02	IGNORED	.100E+32	
78	DIETWSF1	.93002E+01	.45897E+01	IGNORED	.100E+32	
79	DIETCSF1	.22874E+02	.11064E+02	IGNORED	.100E+32	

FINAL RESULTS

LINEAR, MULTIPLE-SEASON, NON-WEIGHTED, DETERMINISIC MODEL -- MODEL 6A1

SECTION 1 -- CONSTRAINTS

NO.	NAME	INITIAL VALUE	FINAL VALUE	STATUS	DISTANCE FROM NEAREST BOUND	LAGRANGE MULTIPLIER
80	DIETSHR1	.22684E+01	.89451E+00	IGNORED	.100E+32	
81	T GRAZD1	.48960E+03	.40673E+06	IGNORED	.100E+32	
82	DIETWSG2	.46121E+02	.59370E+02	IGNORED	.100E+32	
83	DIETCSG2	.26069E+02	.26627E+02	IGNORED	.100E+32	
84	DIETWSF2	.65745E+01	.24471E+01	IGNORED	.100E+32	
85	DIETCSF2	.15967E+02	.84903E+01	IGNORED	.100E+32	
86	DIETSHR2	.52635E+01	.25640E+01	IGNORED	.100E+32	
87	T GRAZD2	.11421E+04	.94832E+06	IGNORED	.100E+32	
88	DIETWSG3	.53857E+02	.64457E+02	IGNORED	.100E+32	
89	DIETCSG3	.28833E+02	.26325E+02	IGNORED	.100E+32	
90	DIETWSF3	.18637E+01	.10000E+01	IGNORED	.100E+32	
91	DIETCSF3	.53641E+01	.32244E+01	IGNORED	.100E+32	
92	DIETSHR3	.10077E+02	.43938E+01	IGNORED	.100E+32	
93	T GRAZD3	.96325E+03	.81108E+06	IGNORED	.100E+32	
94	DIETWSG4	.50178E+02	.69000E+02	IGNORED	.100E+32	
95	DIETCSG4	.34102E+02	.27000E+02	IGNORED	.100E+32	
96	DIETWSF4	.59413E+00	.25410E-14	IGNORED	.100E+32	
97	DIETCSF4	.21267E+01	.10000E+01	IGNORED	.100E+32	
98	DIETSHR4	.13000E+02	.30000E+01	IGNORED	.100E+32	
99	T GRAZD4	.19558E+04	.52428E+06	IGNORED	.100E+32	
100	CAT GRZ1	.48529E+02	.92629E+02	IGNORED	.100E+32	
101	BIS GRZ1	.34436E+02	-.41453E-05	IGNORED	.100E+32	
102	SHP GRZ1	.10294E+02	.73709E+01	IGNORED	.100E+32	
103	ANT GRZ1	.67402E+01	.27314E-14	IGNORED	.100E+32	
104	CAT GRZ2	.48463E+02	.92548E+02	IGNORED	.100E+32	
105	BIS GRZ2	.34752E+02	-.41853E-05	IGNORED	.100E+32	
106	SHP GRZ2	.10402E+02	.74517E+01	IGNORED	.100E+32	
107	ANT GRZ2	.63830E+01	.25879E-14	IGNORED	.100E+32	
108	CAT GRZ3	.48877E+02	.92519E+02	IGNORED	.100E+32	
109	BIS GRZ3	.35399E+02	-.42258E-05	IGNORED	.100E+32	
110	SHP GRZ3	.10534E+02	.74806E+01	IGNORED	.100E+32	
111	ANT GRZ3	.51838E+01	.20357E-14	IGNORED	.100E+32	
112	CAT GRZ4	.48175E+02	.10000E+03	IGNORED	.100E+32	
113	BIS GRZ4	.35075E+02	.22313E-12	IGNORED	.100E+32	
114	SHP GRZ4	.10666E+02	-.13712E-13	IGNORED	.100E+32	
115	ANT GRZ4	.60845E+01	.77414E-14	IGNORED	.100E+32	
116	AUE 1	.90000E+00	.67788E+03	IGNORED	.100E+32	
117	AUE 2	.11690E+01	.87887E+03	IGNORED	.100E+32	
118	AUE 3	.14310E+01	.10830E+04	IGNORED	.100E+32	
119	AUE 4	.17180E+01	.41677E+03	IGNORED	.100E+32	
120	T. AUE	.13992E+01	.71054E+03	IGNORED	.100E+32	
121	OBJ FUNC	-.45557E+04	-.26304E+07	OBJ		

FINAL RESULTS

LINEAR, MULTIPLE-SEASON, NON-WEIGHTED, DETERMINISIC MODEL -- MODEL 6A1

SECTION 2 -- VARIABLES

NO.	NAME	INITIAL VALUE	FINAL VALUE	STATUS	DISTANCE FROM NEAREST BOUND	REDUCED GRADIENT
1	CATTLE 1	.10000E+01	.15956E+04	BASIC	.159E+04:L	
2	BISON 1	.10000E+01	-.10000E-03	BASIC	LOWERBND	
3	SHEEP 1	.10000E+01	.59484E+03	BASIC	.595E+03:L	
4	PRONGHN1	.10000E+01	.33665E-12	NONBASIC	LOWERBND	.12670E+03
5	CATTLE 2	.10000E+01	.15856E+04	BASIC	.159E+04:L	
6	BISON 2	.10000E+01	-.10000E-03	BASIC	LOWERBND	
7	SHEEP 2	.10000E+01	.59434E+03	BASIC	.595E+03:L	
8	PRONGHN2	.10000E+01	.33665E-12	BASIC	LOWERBND	
9	CATTLE 3	.10000E+01	.15856E+04	BASIC	.159E+04:L	
10	BISON 3	.10000E+01	-.10000E-03	BASIC	LOWERBND	
11	SHEEP 3	.10000E+01	.59484E+03	BASIC	.595E+03:L	
12	PRONGHN3	.10000E+01	.33665E-12	BASIC	LOWERBND	
13	CATTLE 4	.10000E+01	.55544E+03	BASIC	.556E+03:L	
14	BISON 4	.10000E+01	.17053E-11	NONBASIC	LOWERBND	.35575E+03
15	SHEEP 4	.10000E+01	-.34451E-12	NONBASIC	LOWERBND	.69534E+02
16	PRONGHN4	.10000E+01	.34106E-12	NONBASIC	LOWERBND	.11459E+03

FORTRAN Program RHS5: Model 5 Series

The code of the FORTRAN program, RHS5, which calculates the right-hand-side values for the Model 5 series, as implemented, follows, along with some sample output.

```
      PROGRAM RHS5 (INPUT,OUTPUT,GOUT,TAPE8=GOUT)

C.....PROGRAM TO THE CALCULATE THE RIGHT-HAND-SIDE VALUES USED IN THE
C.....MODEL 5 SERIES FOR THE GRG2 OPTIMIZATION ALGORITHM.

      INTEGER RUN, NAME1(6), PERCNT(8)
      REAL H, U(5), S(5,2), GR(5,2), L(5), A(5)
      REAL RHSG(5), RHSM, PENALG(5), PENALM(5), M
      REAL FRACTL, STDDEV(8), VARS(5), VARG(5)

C.....NAME DATA
      DATA NAME1 /
     1 60HNAME LINEAR, SINGLE-SEASON, NON-WEIGHTED, STOCHASTIC MODEL  /

C.....CONSTANTS
      DATA H, M /10000., 150. /
      DATA STDDEV /0.0, .25, .52, .84, 1.28, 1.645, 1.96, 3.9/
      DATA PERCNT / 0, 20, 40, 60, 80, 90, 95, 99/

C.....PLANT DATA
      DATA U /.45, .46, .45, .46, .37/
      DATA ((GR(I,J),I=1,5),J=1,2)/
     1 600., 240., 70., 55., 100.,   13., 11., 21., 23., 11./
      DATA ((S(I,J),I=1,5),J=1,2)/
     1 50., 3*5., 15.,   2*5., 2*10., 20./
      DATA L /.32, .40, .42, .46, .33/

C.....COMPUTE VARIANCES
      DO 100 I = 1,5
        VARG(I) = (GR(I,1) * GR(I,2) / 100.)**2
        VARS(I) = (S(I,1) * S(I,2) / 100.)**2
 100  CONTINUE

C.....COMPUTE AVIALABLE

 90   DO 130 I=1,5
        A(I) = H * (S(I,1) + GR(I,1)) * (1. - L(I))
 130  CONTINUE

C.....COMPUTE PENALTY FUNCT.'S FOR SITE-MAINTENANCE CONSTRAINT
      DO 150 I=1,5
 150    PENALM(I) = SQRT((H * (1.- L(I)))**2 * VARS(I))
     1           + SQRT((H * (1.- L(I)))**2 * VARG(I))

C.....COMPUTE PENALTY FUNCT.'S FOR OVER-GRAZING CONSTRAINTS
      DO 170 I=1,5
        PENALG(I) = SQRT((H * U(I) * (1.- L(I)))**2 * VARS(I))
     1           + SQRT((H * U(I) * (1.- L(I)))**2 * VARG(I))
 170  CONTINUE
```

```
      DO 600 RUN = 1,8

        IF (RUN.EQ.1) PRINT (8,1)
1       FORMAT (*ROWS  -  BOUNDS FOR CONSTRAINTS*)
        IF (RUN.NE.1)PRINT(8,2)(NAME1(I),I=1,6),PERCNT(RUN),PERCNT(RUN)
2       FORMAT (*GO*/*REVISE*/6A10,*  --  *,I3,*% LEVEL*/
     1  *ROWS  -  BOUNDS FOR CONSTRAINTS  -- *,I3,*% LEVEL*)

        FRACTL = STDDEV(RUN)
        RHSM = 0.
        DO 500 I = 1,5
          RHSG(I) = A(I) * U(I) - FRACTL * PENALG(I)
          RHSM = RHSM + A(I) - FRACTL * PENALM(I)
500     CONTINUE
        RHSM = RHSM - M

        I = 1
        PRINT (8,3) I, RHSM
3       FORMAT (T2,*L*,T4,I3,T11,G20.14)
        DO 700 I = 2,6
700       PRINT (8,3) I, RHSG(I-1)
        PRINT (8,5)
5       FORMAT (T2,*N*,T6,*7*,T9,*23*/T2,*0*,T5,*24*/*END*)

600     CONTINUE
        PRINT (8,4)
4       FORMAT (*GO*/*STOP*/*/EOF*)

      END
```

```
ROWS  - BOUNDS FOR CONSTRAINTS
 L  1     7419349.9999999
 L  2     1989000.0000000
 L  3     676199.99999999
 L  4     195750.00000000
 L  5     149040.00000000
 L  6     285085.00000000
 N  7  23
 O  24
END
GO
REVISE
NAME QUADRATIC, SINGLE-SEASON, NON-WEIGHTED, STOCHASTIC MODEL  --  20% LEVEL
ROWS  - BOUNDS FOR CONSTRAINTS  --  20% LEVEL
 L  1     7179282.4999999
 L  2     1927417.5000000
 L  3     657811.49999999
 L  4     185832.00000000
 L  5     140873.85000000
 L  6     276408.50000000
 N  7  23
 O  24
END
GO
```

FORTRAN Program RHS6: Model 6 Series

The code of the FORTRAN program, RHS6, which calculates the right-hand-side values for the Model 6 series, as implemented, follows, along with some sample output.

```
      PROGRAM RHS6 (INPUT,OUTPUT,GOUT,TAPE8=GOUT)

C.....PROGRAM TO CALCULATE THE RIGHT HAND SIDE VALUE USED IN THE
C.....MODEL 6 SERIES FOR GRG2 OPTIMIZATION ALGORITHM.

      REAL H, S(5), GR(5,4), U(5,4), L(5,4), SM(4)
      REAL PENALM(4), PENALG(5,4), RHSM(4), RHSG(5,4)
      REAL VARS(5), VARG(5,4), STDDEV(8)

      INTEGER NAME(6), PERCNT(8)
      INTEGER RUN, I, K, LL, M

C.....DATA NAMES
      DATA NAME /
     1 60HNAME LINEAR, MULTIPLE SEASON, NON-WEIGHTED, STOCHASTIC MODEL/

C.....DATA CONSTANTS
      DATA H /10000.0/
      DATA STDDEV / 0.0, .25, .52, .84, 1.28, 1.645, 1.96, 3.9/
      DATA PERCNT / 0, 20, 40, 60, 80, 90, 95, 99/

C.....PLANT DATA
      DATA S /50., 3*5., 15./

      DATA ((U(I,K),I=1,5),K=1,4)/
     1 .3, .1, .3, 2*.1,
     2 .1, .3, .1, .3, .1,
     3 4*.5, .3,
     4 5*.7/

      DATA ((GR(I,K),I=1,5),K=1,4)/
     1 240., 200., 20., 45., 30.,
     2 360., 20., 50., 5., 60.,
     3 0., 20., 0., 5., 10.,
     4 5*0./

      DATA ((L(I,K),I=1,5),K=1,4)/
     1 .1, .05, 2*.1, .05,
     2 .05, .1, .05, .2, .05,
     3 .1, .5, 2*.6, .2,
     4 5*.7/

      DATA VARS  / 6.25, 0.0625, 0.25, 0.25, 9./

      DATA ((VARG(I,K),I=1,5),K=1,4)/
     1 10., 5., 25., 20., 5.,
     2 15., 10., 35., 30., 10.,
     3 25., 30., 45., 40., 30.,
     4 5*0./
```

```
      DATA SM /150., 100., 50., 150./

C.....CALCULATE RIGHT-HAND SIDE PENALTY FUNCTION FOR OVER-GRAZING &
C..... SITE MAINTENANCE CONSTRAINTS
      DO 100 K =1,4
        PENALM(K) = 0.
        DO 100 I = 1,5
          PENALG(I,K) = 0.

          VARG(I,K) = (GR(I,K) * VARG(I,K) / 100.)**2

          DO 110 M = 1,K
            TEMP = H
            DO 120 LL = M,K
 120          TEMP = TEMP * (1. - L(I,LL))
            IF (M.EQ.1) TEMP2 = TEMP

            PENALG(I,K) = PENALG(I,K) + SQRT((TEMP*U(I,K))**2*VARG(I,M))
            PENALM(K) = PENALM(K) + SQRT(TEMP**2 * VARG(I,M))
 110      CONTINUE

          PENALG(I,K) = PENALG(I,K) + SQRT((TEMP2*U(I,K))**2 * VARS(I))
          PENALM(K) = PENALM(K) + SQRT(TEMP2**2 * VARS(I))
 100  CONTINUE


      DO 200 RUN = 1,8
        FRACTL = STDDEV(RUN)
        IF (RUN.NE.1) PRINT(8,3)
 3      FORMAT (*GO*/*REVISE*)
        IF (RUN.EQ.1) PRINT(8,4)
 4      FORMAT (*ROWS  - BOUNDS FOR CONSTRAINTS*)
        IF (RUN.NE.1) PRINT(8,5)(NAME(I),I=1,6),PERCNT(RUN),PERCNT(RUN)
 5      FORMAT (6A10,*  --  *,I3,*% LEVEL*/
     1  *ROWS  - BOUNDS FOR CONSTRAINTS  -- *,I3,*% LEVEL*)


        DO 199 K = 1,4
          RHSM(K) = 0.
          DO 204 I = 1,5
            RHSG(I,K) = 0.

            TEMP = S(I) * H
            DO 201 M = 1,K
 201          TEMP = TEMP * (1. - L(I,M))

            RHSM(K) = RHSM(K) + TEMP
            RHSG(I,K) =  TEMP * U(I,K)

            DO 202 M = 1,K
              TEMP = GR(I,M) * H

              DO 203 LL = M,K
 203            TEMP = TEMP * (1. - L(I,LL))

              RHSM(K) = RHSM(K) + TEMP
 202          RHSG(I,K) = RHSG(I,K) + TEMP * U(I,K)
            RHSG(I,K) = RHSG(I,K) - FRACTL * PENALG(I,K)
```

```
204       CONTINUE
          RHSM(K) = RHSM(K) - FRACTL * PENALM(K) - SM(K)
199     CONTINUE

        DO 300 K = 1,4
300       PRINT (8,6) K, RHSM(K)
6       FORMAT (T2,*L*,T4,I3,T11,G20.14)

        KK = 4
        DO 400 K = 1,4
          DO 400 I = 1,5
          KK = KK + 1
          PRINT (8,6) KK,RHSG(I,K)
400     CONTINUE
        PRINT (8,7)
7       FORMAT (T2,*L*,T5,*25*,T9,*36*/
     1  T2,*N*,T5,*37*,T8,*120*/T2,*O*,T4,*121*/*END*)
200   CONTINUE
      PRINT (8,8)
8     FORMAT (*GO*,/,*STOP*,/,*/EOF*)
      STOP
      END
```

```
ROWS  - BOUNDS FOR CONSTRAINTS
 L   1      5659849.9999998
 L   2      9897024.9999993
 L   3      7692274.9999995
 L   4      2307547.4999998
 L   5      782999.99999999
 L   6      194750.00000000
 L   7      67500.000000000
 L   8      45000.000000000
 L   9      42750.000000000
 L  10      589949.99999999
 L  11      579824.99999999
 L  12      68874.999999999
 L  13      120000.00000000
 L  14      97612.499999999
 L  15      2654775.0000000
 L  16      533187.49999999
 L  17      137750.00000000
 L  18      89999.999999998
 L  19      258269.99999999
 L  20      1115005.5000000
 L  21      223938.74999999
 L  22      57854.999999998
 L  23      37799.999999999
 L  24      180788.99999999
 L  25  36
 N  37 120
 0 121
END
GO
REVISE
NAME LINEAR, MULTIPLE-SEASON, NON-WEIGHTED, STOCHASTIC MODEL  --  20% LEVEL
ROWS  - BOUNDS FOR CONSTRAINTS - 20% LEVEL
 L   1      5531443.7499998
 L   2      9587899.9999993
 L   3      7448275.9374995
 L   4      2234347.7812498
 L   5      765112.49999999
 L   6      192315.62500000
 L   7      63787.500000000
 L   8      42862.500000000
 L   9      41681.250000000
 L  10      571460.62499999
 L  11      571902.18749999
 L  12      63543.124999999
 L  13      113970.00000000
 L  14      95172.187499999
 L  15      2571572.8125000
 L  16      522835.15624999
 L  17      127086.25000000
 L  18      84979.999999998
 L  19      250613.24999999
 L  20      1080060.5812500
 L  21      219590.76562499
 L  22      53376.224999998
 L  23      35691.599999999
 L  24      175429.27499999
 L  25  36
 N  37 120
 0 121
END
GO
REVISE
```

Gradient of Model 2B

The gradient of Model 2B is derived as follows:

n=1 $\Sigma_{i=1}^{I} -T_1 \Sigma_{j=1}^{J} C_{j1}$

$+ \Sigma_{i=1}^{I} [-T_1 \Sigma_{j=1}^{J} C_{j1} D_{ij1}]\ U_{i2}\ (1-L_{i2})$

$+ \Sigma_{i=1}^{I} [-T_1 \Sigma_{j=1}^{J} C_{j1} D_{ij1}]\ U_{i3}\ (1-L_{i2})(1-L_{i3})$

$+ \Sigma_{i=1}^{I} [-T_1 \Sigma_{j=1}^{J} C_{j1} D_{ij1}]\ U_{i4}\ (1-L_{i2})(1-L_{i3})(1-L_{i4})$

n=2 $\Sigma_{i=1}^{I} -T_2 \Sigma_{j=1}^{J} C_{j2}$

$+ \Sigma_{i=1}^{I} [-T_2 \Sigma_{j=1}^{J} C_{j2} D_{ij2}]\ U_{i3}\ (1-L_{i3})$

$+ \Sigma_{i=1}^{I} [-T_2 \Sigma_{j=1}^{J} C_{j2} D_{ij2}]\ U_{i4}\ (1-L_{i3})(1-L_{i4})$

n=3 $\Sigma_{i=1}^{I} -T_3 \Sigma_{j=1}^{J} C_{j3}$

$+ \Sigma_{i=1}^{I} [-T_3 \Sigma_{j=1}^{J} C_{j3} D_{ij3}]\ U_{i4}\ (1-L_{i4})$

n=4 $\Sigma_{i=1}^{I} -T_4 \Sigma_{j=1}^{J} C_{j4}$

Thus,

$$F(x_{jn}) = [(-T_n C_{jn})(1+\Sigma_{i=1}^{I}(D_{ijn}\Sigma_{m=n+1}^{N}(U_{im}\Pi_{l=n+1}^{N}(i-L_{il}))))]$$

for all i and n